JANUARY, 1958

JOURNAL OF THE IRON AND STEEL INSTITUTE

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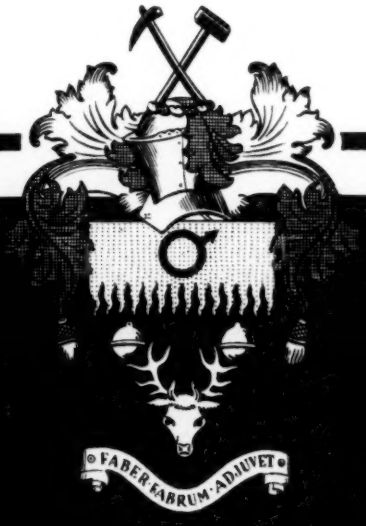

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A 25½" × 56" Duplex Indefinite Chill Work Roll for a continuous Hot Strip Mill in Holland, being loaded aboard ship in the Tees.

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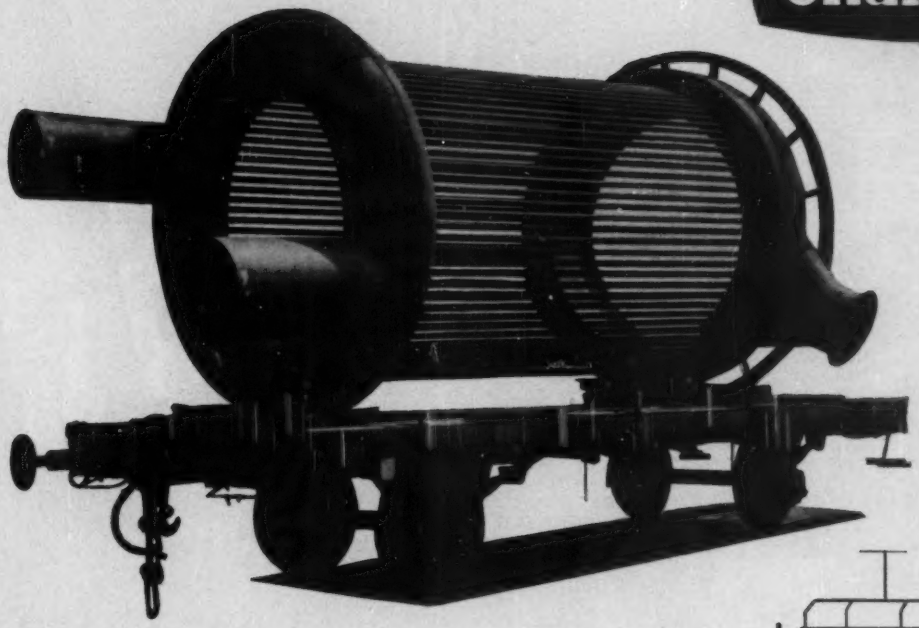

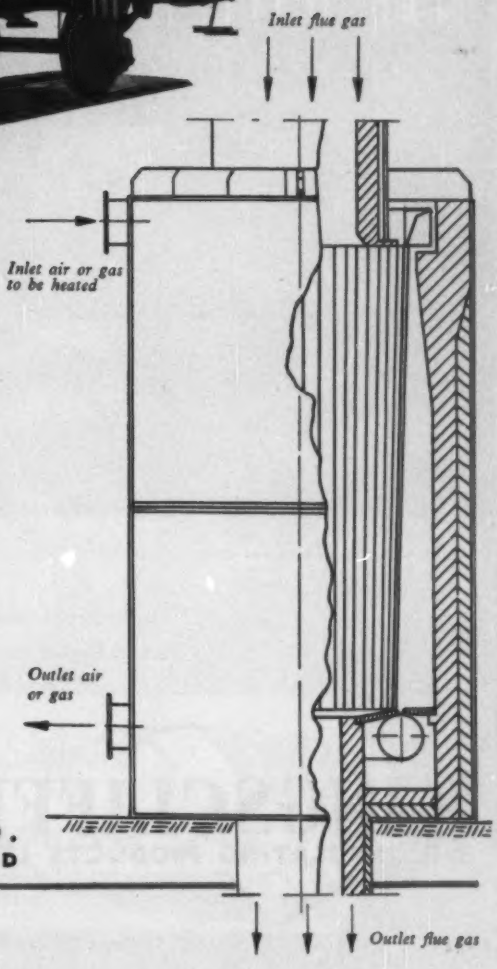

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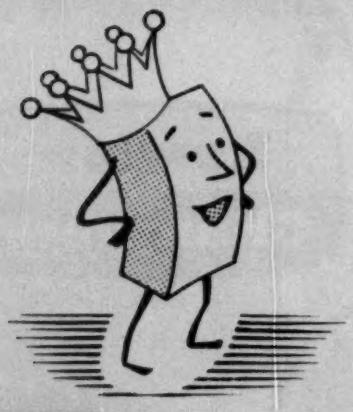

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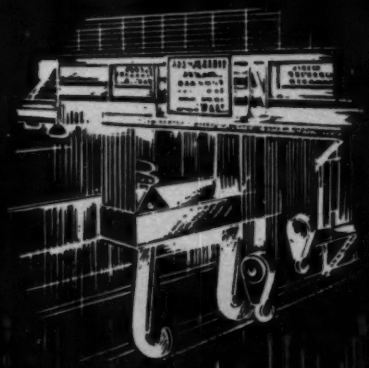

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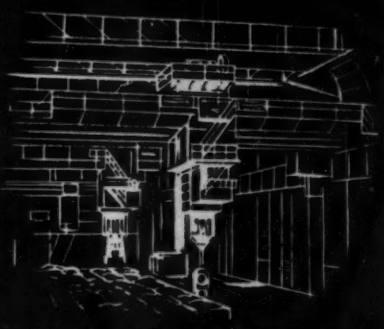

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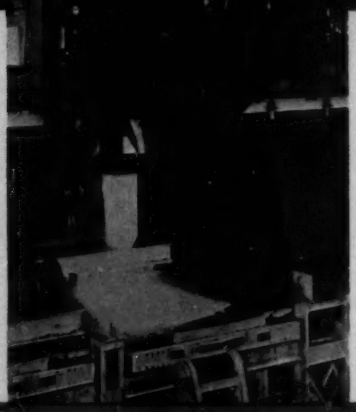

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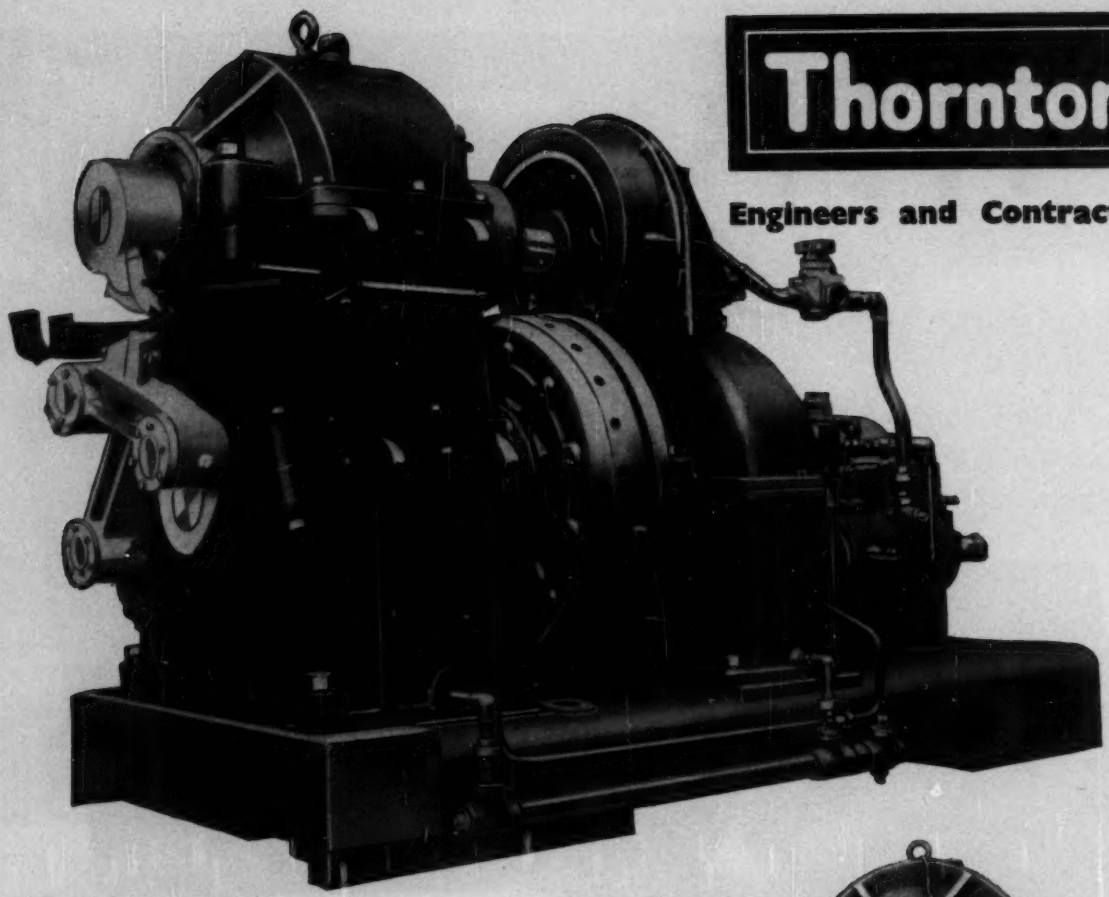

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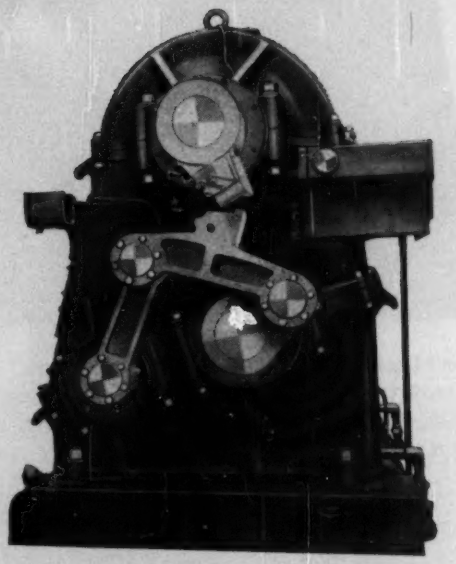

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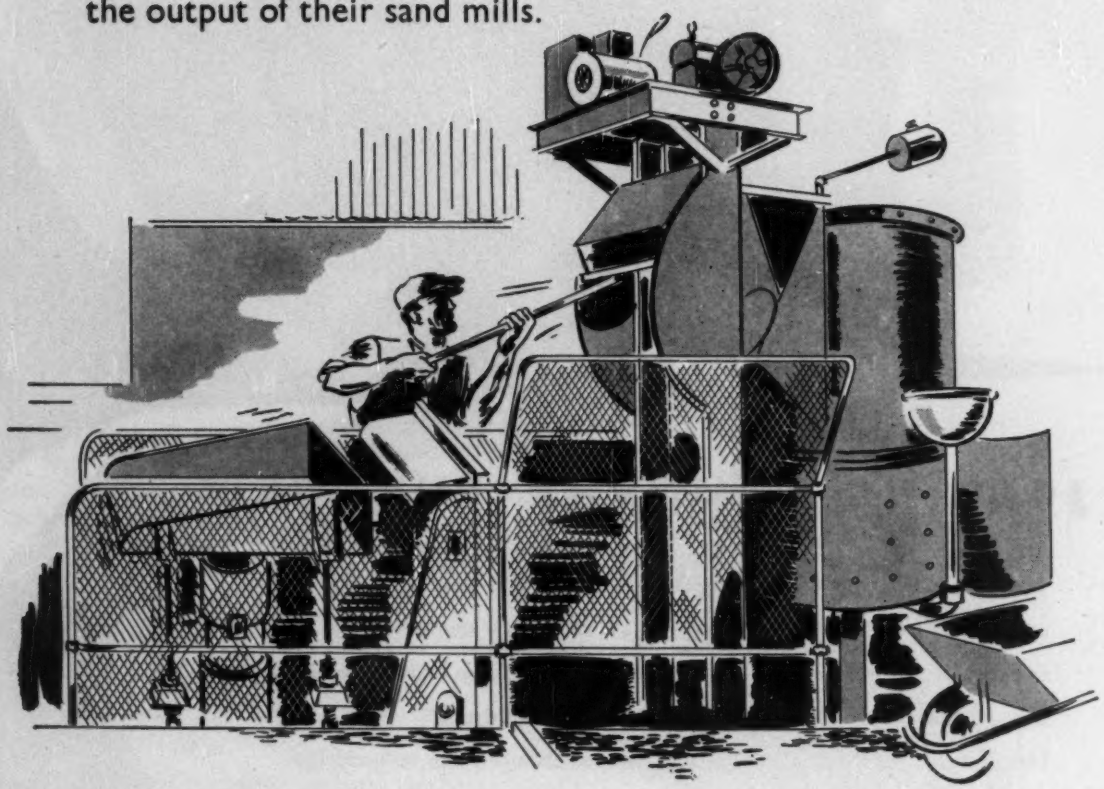

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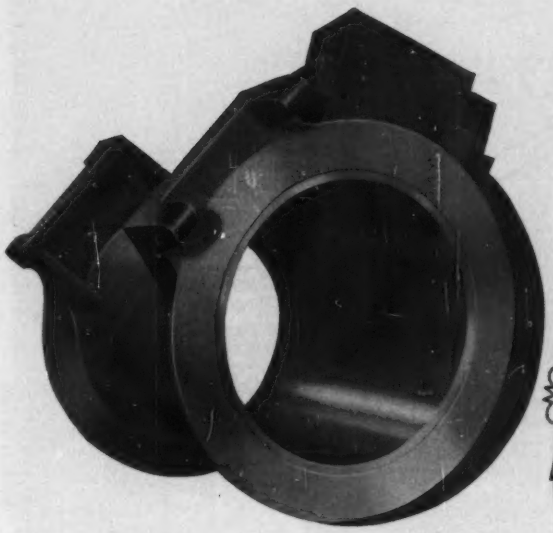

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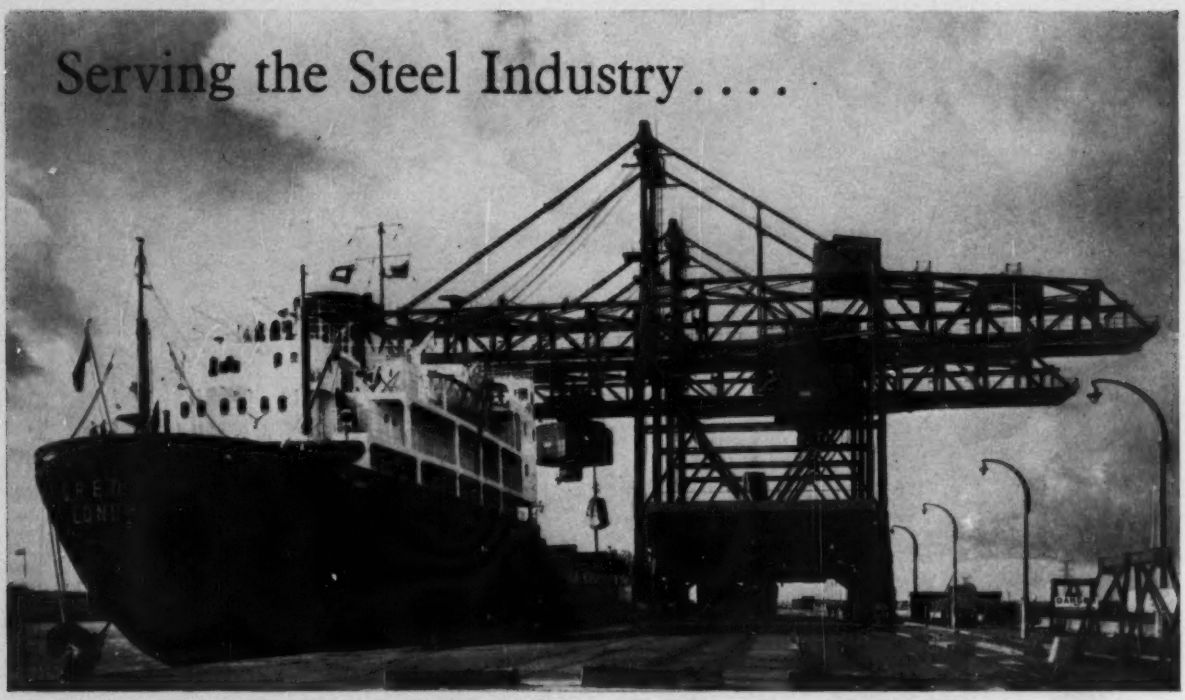

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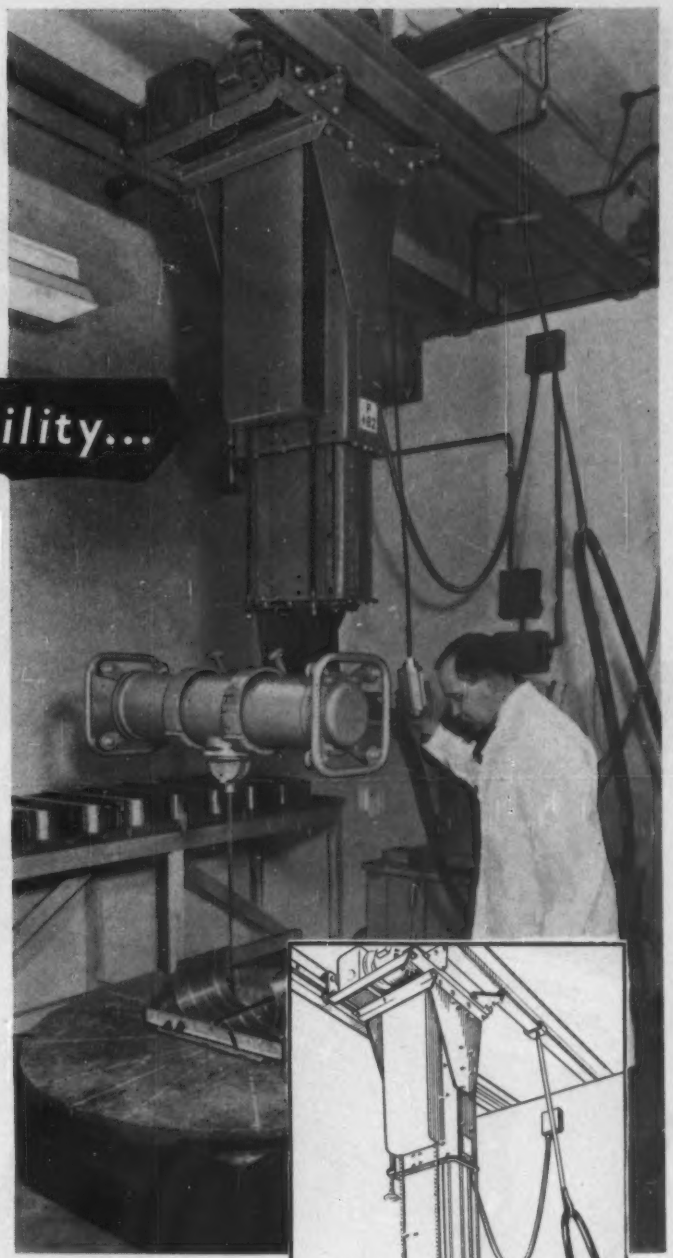
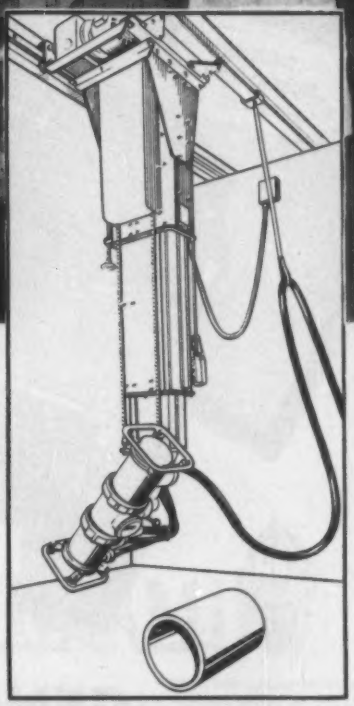


Photograph by courtesy of Palmer X-ray, London.



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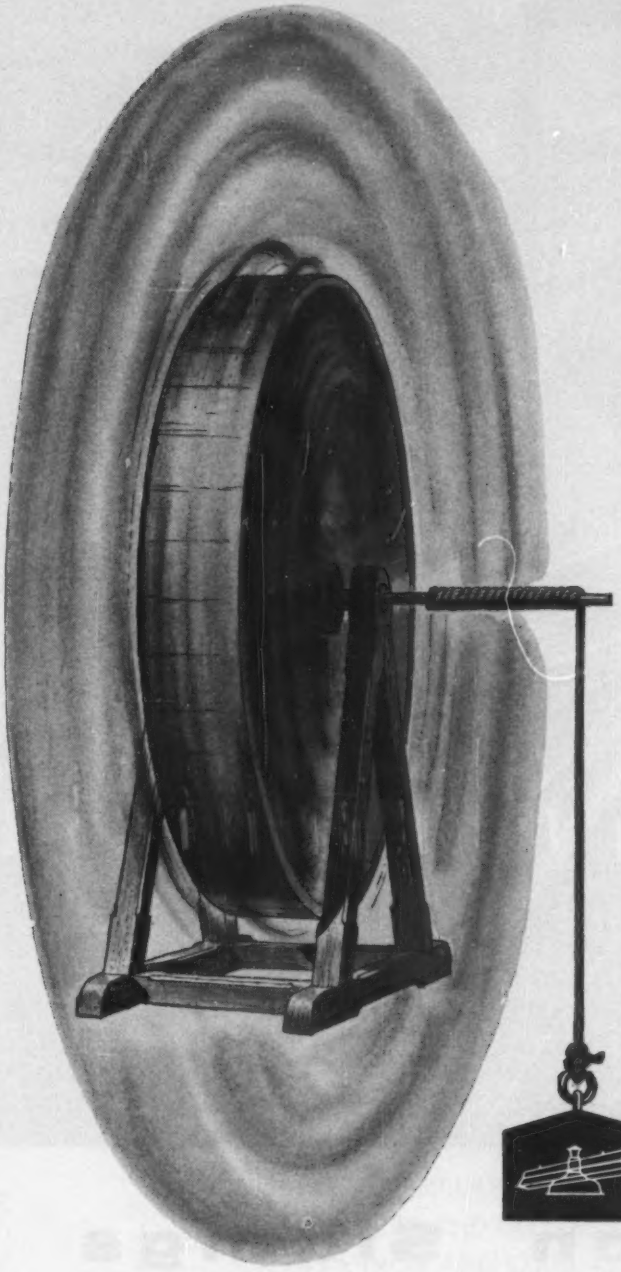

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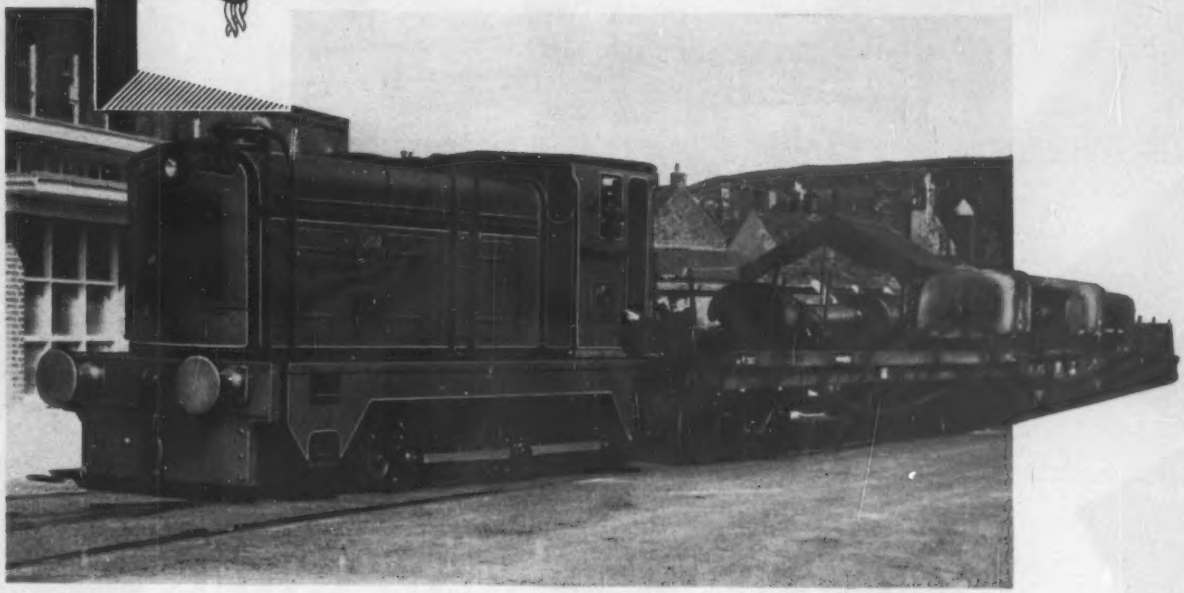

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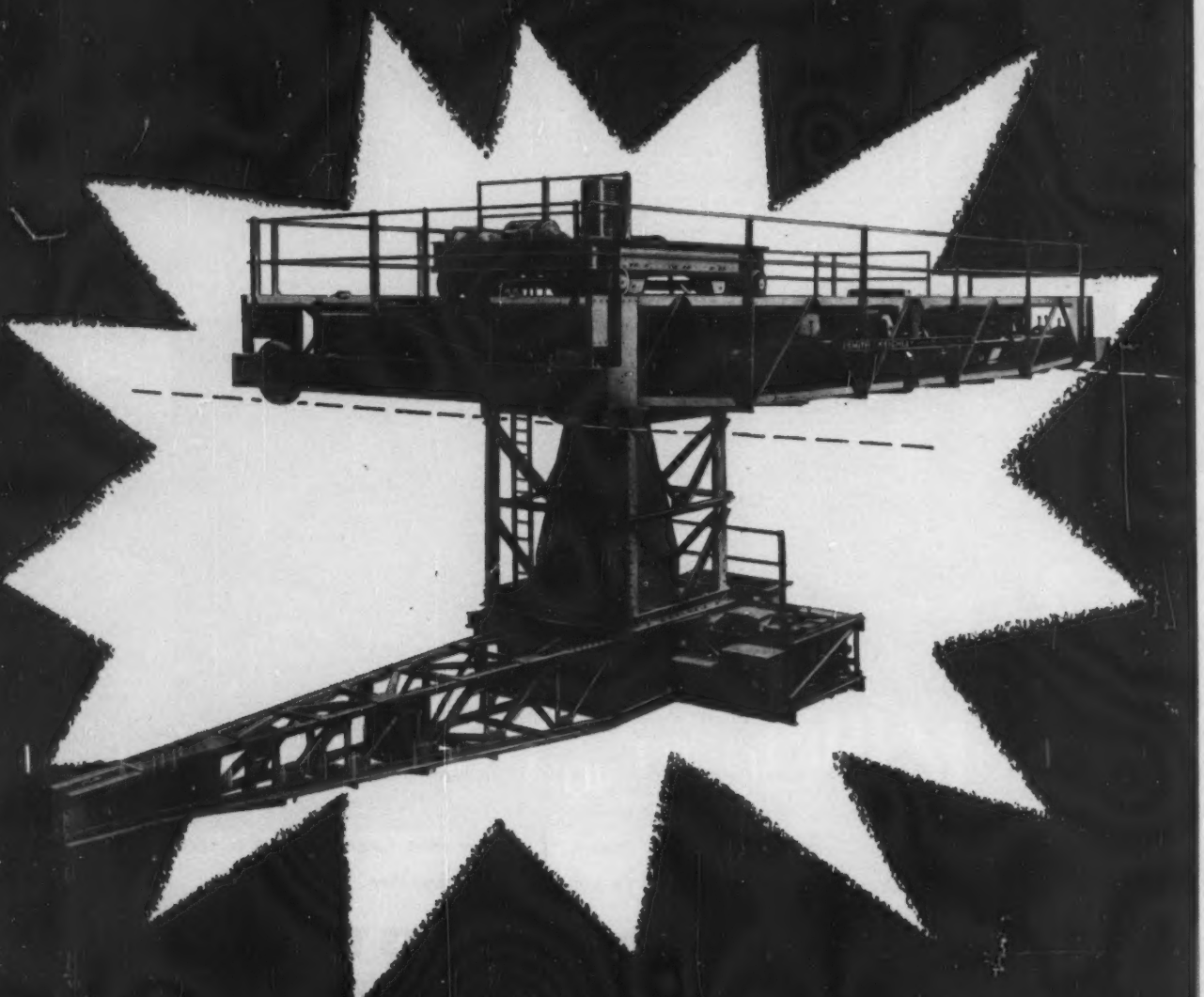

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Staffordshire Landscapes

Scenes such as these are common in South Staffordshire. A century lies between the prime years of the foreground, and the present day development behind.

Though the occupants of the new houses may give little thought to the sunken canal boat, the progress which began its decay may also have brought their forefathers to the district to share, and to play their part in the swelling industrial activity which was growing from the pioneering spirit of the early Iron Masters.

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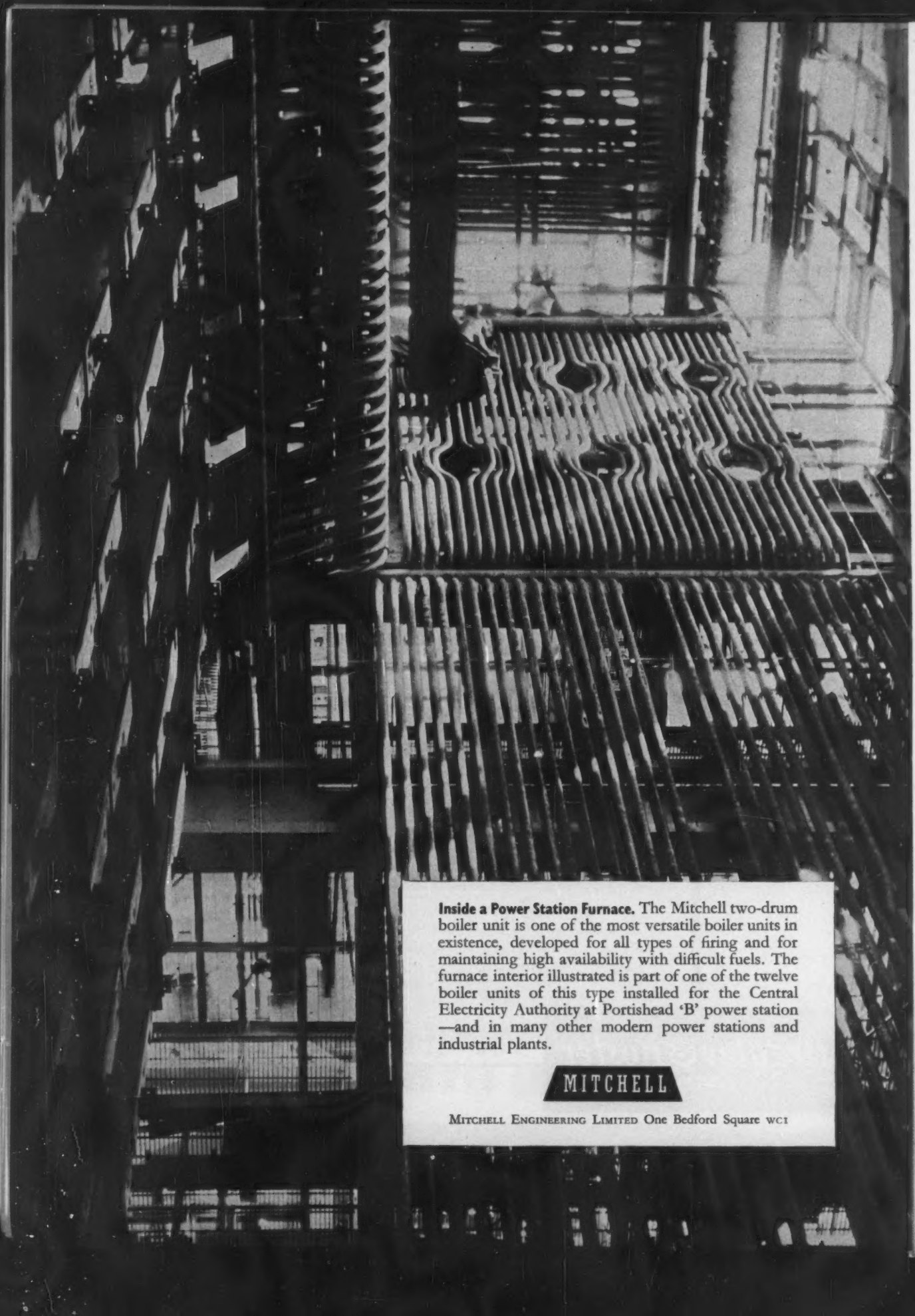

Inside a Power Station Furnace. The Mitchell two-drum boiler unit is one of the most versatile boiler units in existence, developed for all types of firing and for maintaining high availability with difficult fuels. The furnace interior illustrated is part of one of the twelve boiler units of this type installed for the Central Electricity Authority at Portishead 'B' power station —and in many other modern power stations and industrial plants.

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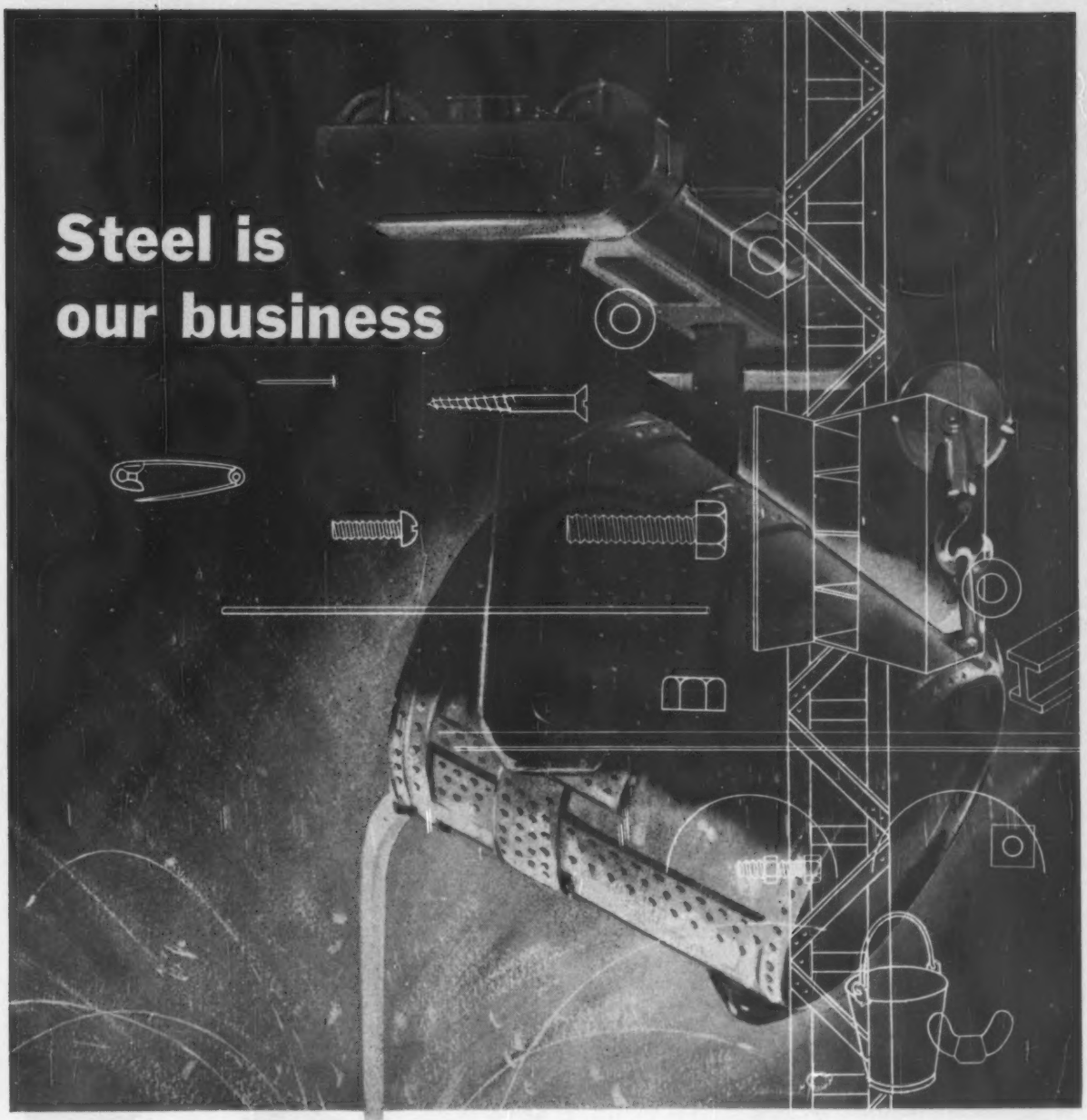

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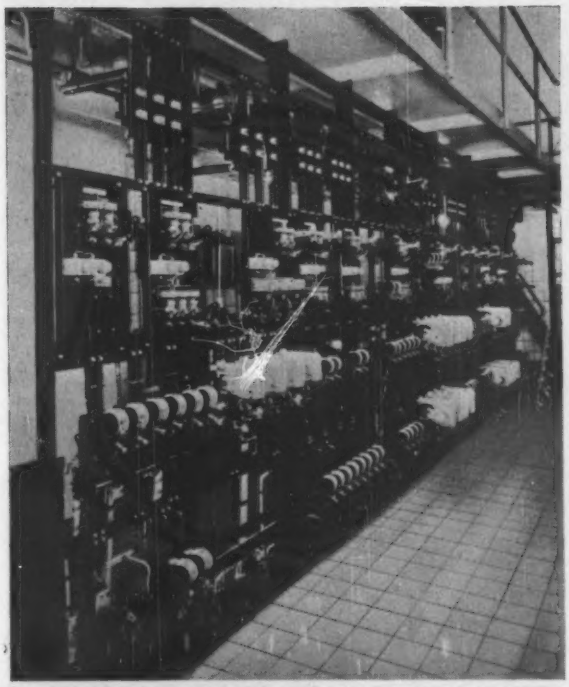
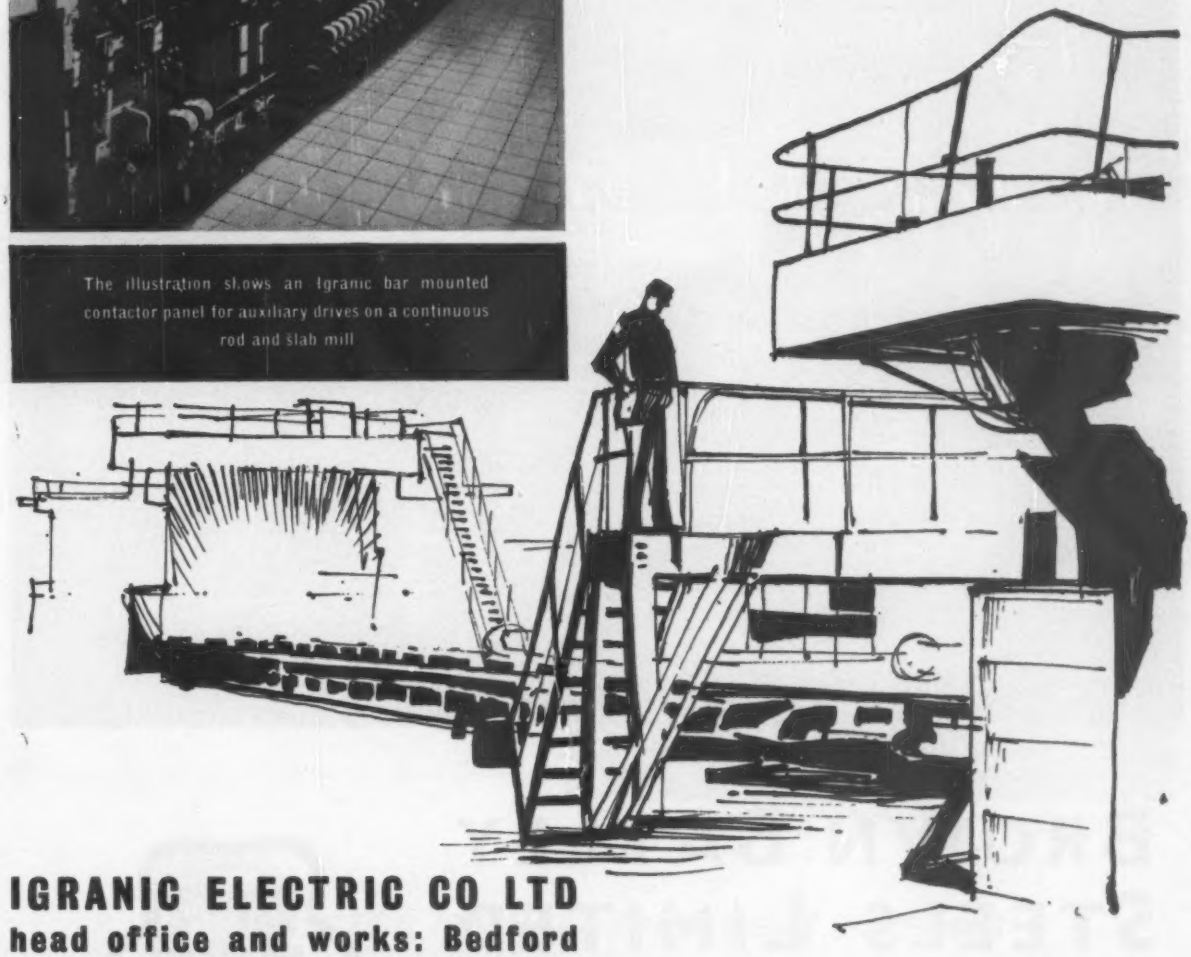
serving every industry



That Igranic does indeed serve
industry is characteristically
exemplified in the production of Iron and Steel.
All over the country—at steelworks, blast-furnaces,
rolling mills, foundries and allied installations,
all geared for maximum production—Igranic Control
Gear is operating consistently under the
most arduous conditions.
In this, as in so many other basic industries,
Igranic equipment has a reputation for reliability
equal in every way to the plant it serves so well.

The illustration shows an Igranic bar mounted contactor panel for auxiliary drives on a continuous rod and slab mill



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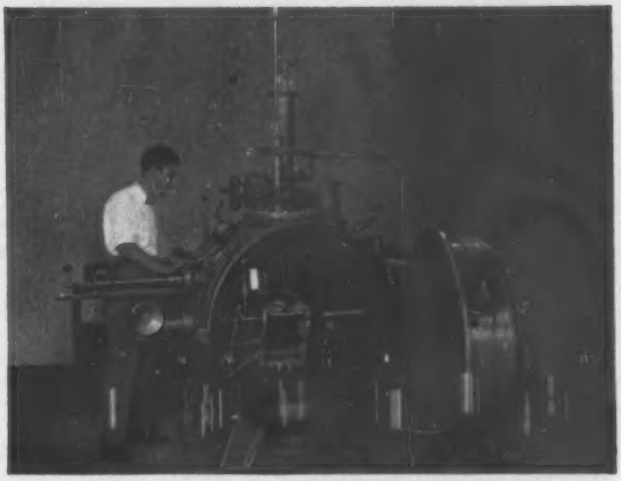
WILD BARFIELD NRC*

Vacuum Melting

INDUCTION AND ARC FURNACES

The experience of the National Research Corporation, who have built and operated more high vacuum furnaces than any other company in the world, and the facilities in Britain of Wild-Barfield combine to offer unsurpassed vacuum melting equipment.
Both arc and induction furnaces are available, the former with consumable or non-consumable electrodes, cold mould or skull type. Induction heated equipments include the N R C patented semi-continuous vacuum melting furnaces.



Model 2555 Vacuum Induction Furnace with melting capacity of 50 pounds of steel. Other standard furnaces have capacities of 12 to 3,000 pounds.

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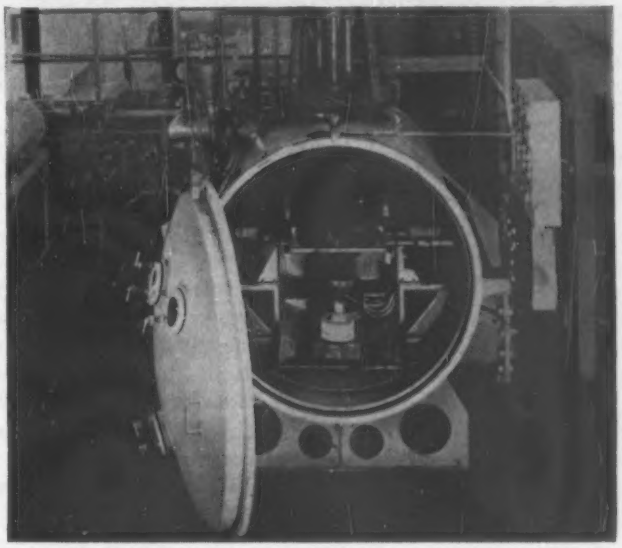
Melting, Alloying, and Purifying; Centrifugal, Ingot, Shape, and Investment Casting; Sintering, Brazing, Degassing and Heat-Treating.

ARC FURNACES FOR ...

Melting and alloying high temperature or reactive metals such as niobium, tantalum, cobalt, zirconium and titanium.



Model 2705 Non-Consumable Arc Skull Furnace with a capacity of 50 pounds of titanium. Other standard vacuum arc furnaces have capacities of 8 to 10,000 pounds of titanium.

OTHER VACUUM EQUIPMENTS

- **Vacuum Fusion Gas Analyser**
- **Hydrogen Analyser**
- **Resistance Furnaces**
- **High Vacuum Diffusion Pumps**

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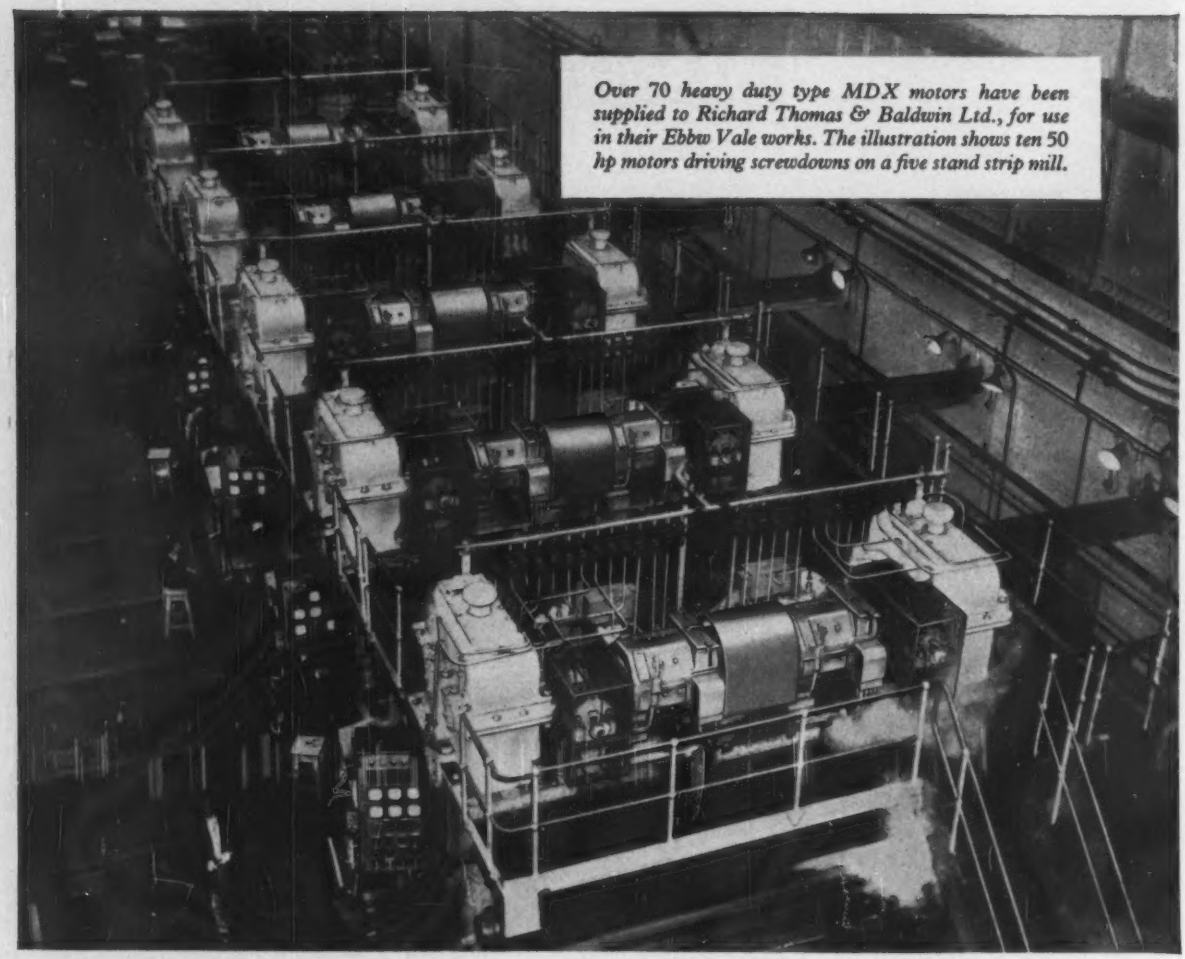
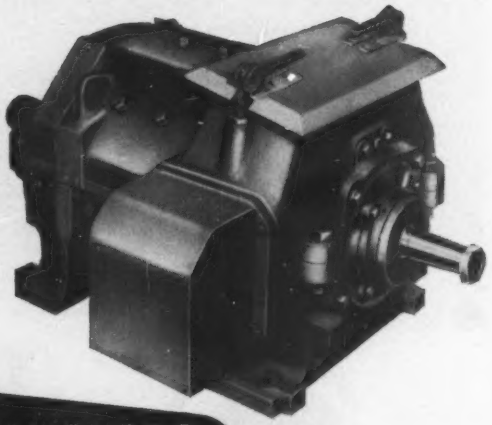


Over 70 heavy duty type MDX motors have been supplied to Richard Thomas & Baldwin Ltd., for use in their Ebbw Vale works. The illustration shows ten 50 hp motors driving screwdowns on a five stand strip mill.

All motors here are type MDX

Metrovick type MDX motors have been specially designed to operate under the arduous conditions of iron and steel works. Their strength and reliability, and the exceptionally low inertia of the rotating parts make these machines ideal for driving a wide range of steelworks equipment. The use of mica and glass insulation suitable for high temperature operation enables the motor to withstand heavy overloads.
Available totally enclosed, up to 200 hp, or self-ventilated, up to 250 hp.



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Metrovick Motors for Trouble Free Service

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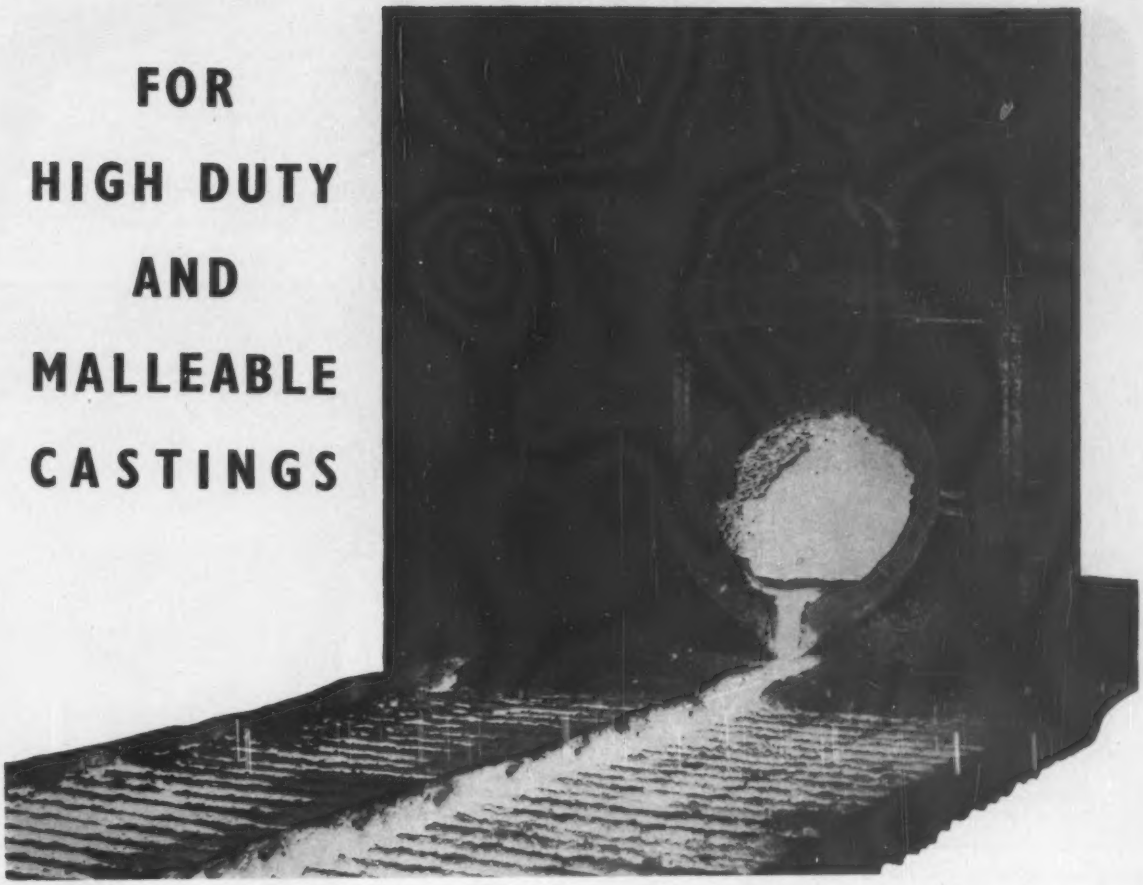

The seven standard grades of Stanton Dale Refined Pig Iron

GRADES:	A	B	C	D	E	F	G
SILICON %	1·9–2·1	1·4–1·6	0·9–1·1	2·25–2·5	0·9–1·1	1·4–1·6	1·9–2·1
SULPHUR %	0·06	0·07	0·08	0·05	0·08	0·07	0·06
PHOSPHORUS %	0·6–0·7	0·6–0·7	0·6–0·7	0·4–0·5	0·25	0·25	0·25
MANGANESE %	0·8–1·5	0·8–1·5	0·8–1·5	0·8–1·5	0·8–1·5	0·8–1·5	0·8–1·5
TOTAL CARBON %	2·7–3·0				2·8–3·1		

In addition to the above other grades of Dale Refined Iron can be supplied to meet more exacting demands which call for alloy additions and special processing.

STANTON *Dale Refined* PIG IRON

THE STANTON IRONWORKS COMPANY LIMITED NEAR NOTTINGHAM

A complete engineering service

Power generation · Furnace electrics · Rolling mill drives · Locomotives
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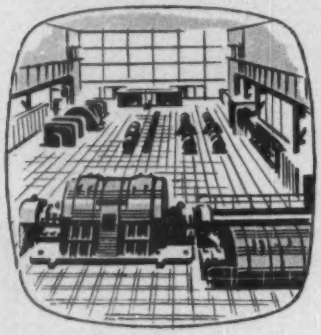
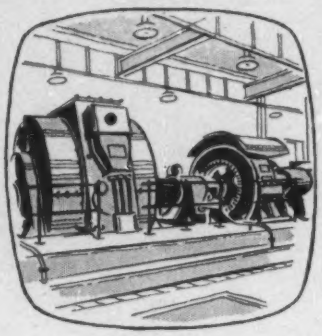
Half a century of world-wide engineering experience stands behind 'ENGLISH ELECTRIC' service to the steel industry.



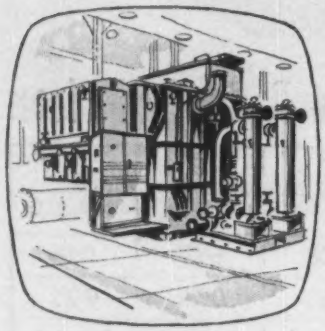
FRANCE

The first 'twin-drive' in France—on an 8,000 h.p. plate mill at Lorraine—Escaut, Longwy. 'ENGLISH ELECTRIC' have specialised in 'twin-drives' since 1923.



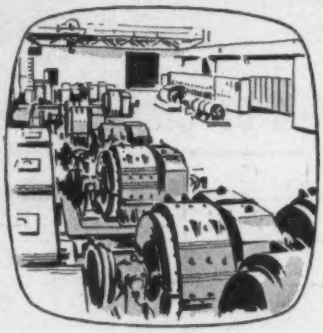
INDIA

The 7,000 h.p. generating set and main drives for the roughing and finishing stands of a Morgan continuous billet mill at the Indian Iron & Steel Company Limited.



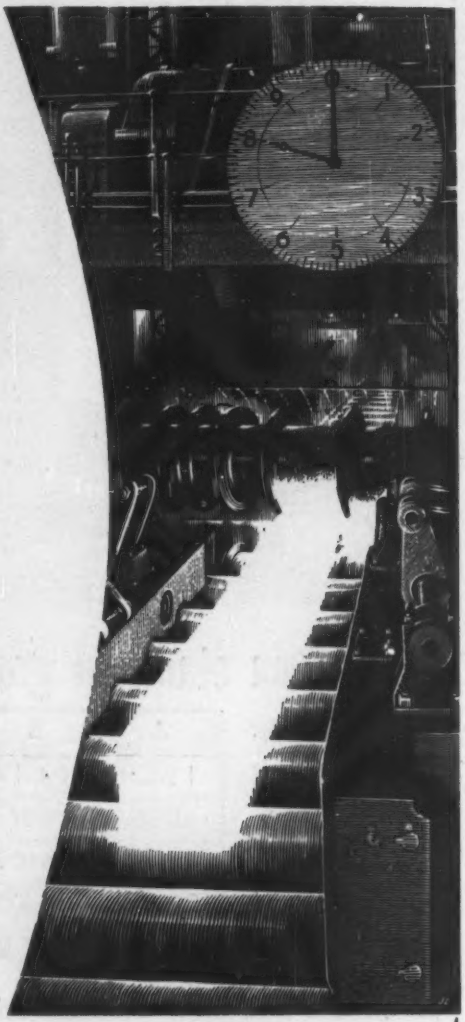
GT. BRITAIN

Supplied to Samuel Fox and Co. Ltd., Sheffield, a transformer for a 60-ton arc furnace in addition to many drives for rolling mills, including a recently installed 5,000 h.p. blooming mill.



NORWAY

Main drives totalling 7,850 h.p., rectifiers, control equipment and over 6,000 h.p. of auxiliary drives were supplied to rolling mills at A/S Norsk Jernverk.



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steelworks equipment

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Metal Industries Division, Stafford
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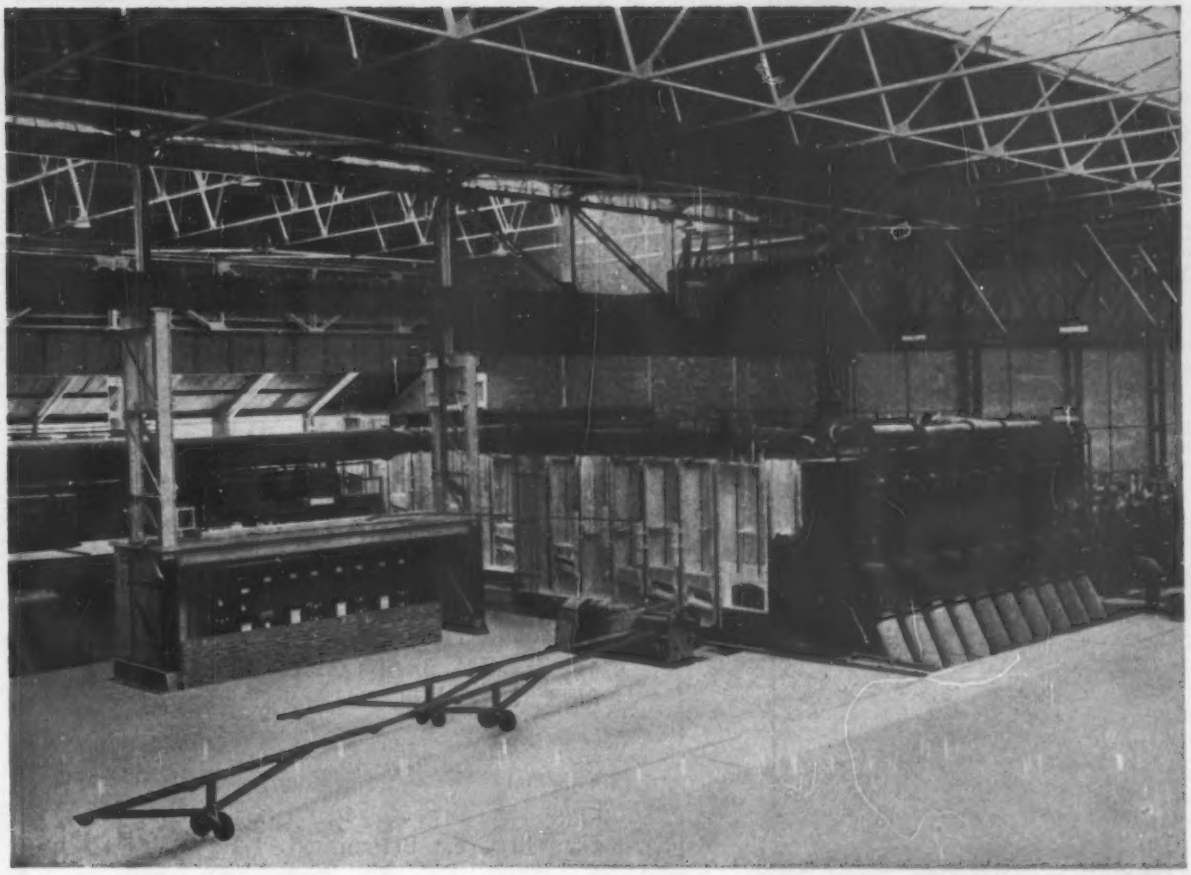

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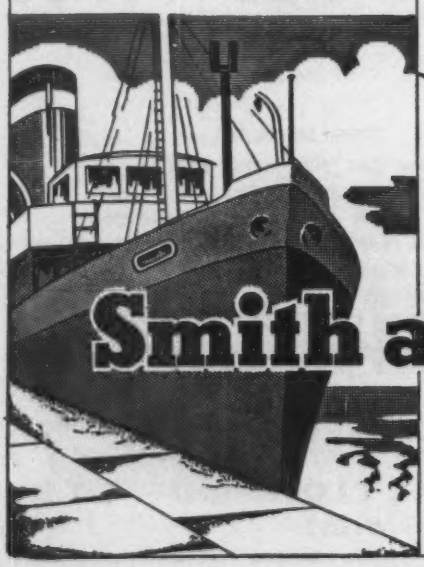

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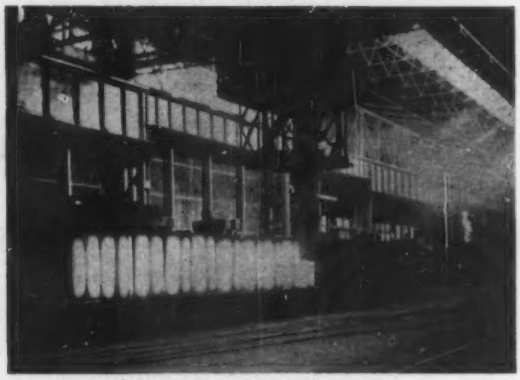
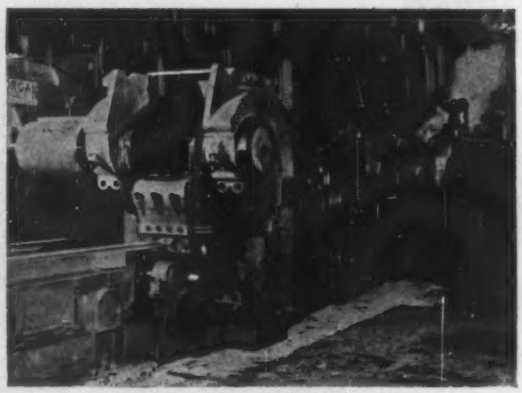


STRIPPING BAY



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BLOOMS 5″ UP TO 9″

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ROUNDS 5G. TO $\frac{9}{16}$″

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RODS IN 500LB. COILS
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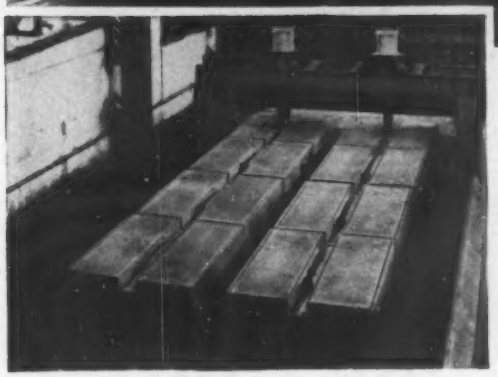
ROD CONVEYOR

ELPIT

INSTALLATION
recently commissioned at the Appleby-Frodingham Steel Company, (Branch of the United Steel Companies Limited), Scunthorpe.



This Electric Soaking Pit with a holding capacity of eight 10 ton slab ingots, was specifically designed for short track time steel. This is attaining outputs in excess of 2,000 ton/week at overall energy consumptions of about 30 kWhrs/ton. Heating without scale formation results in an increased slab yield of about 0.75%.

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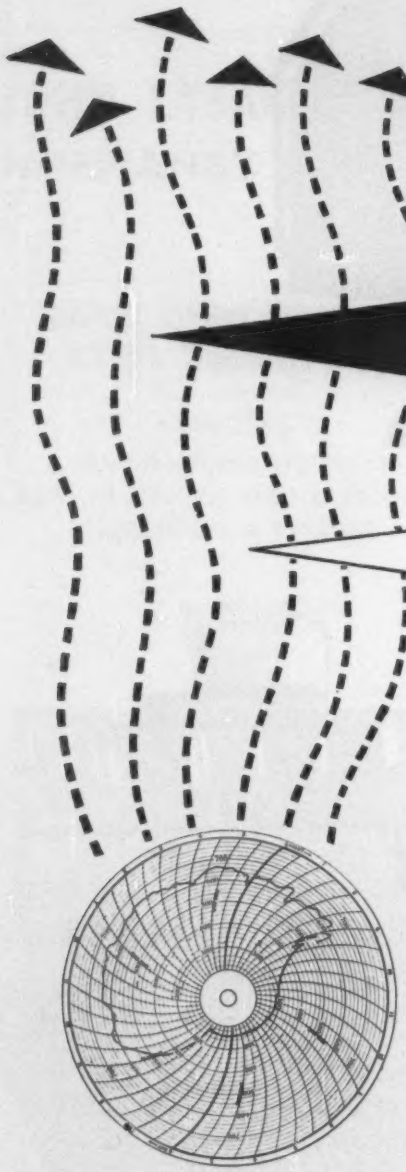

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THE SUREST WAY TO WASTE HEAT from your furnaces and boiler settings is to ignore the need for suitable insulation.

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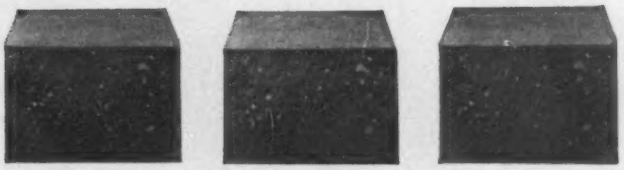

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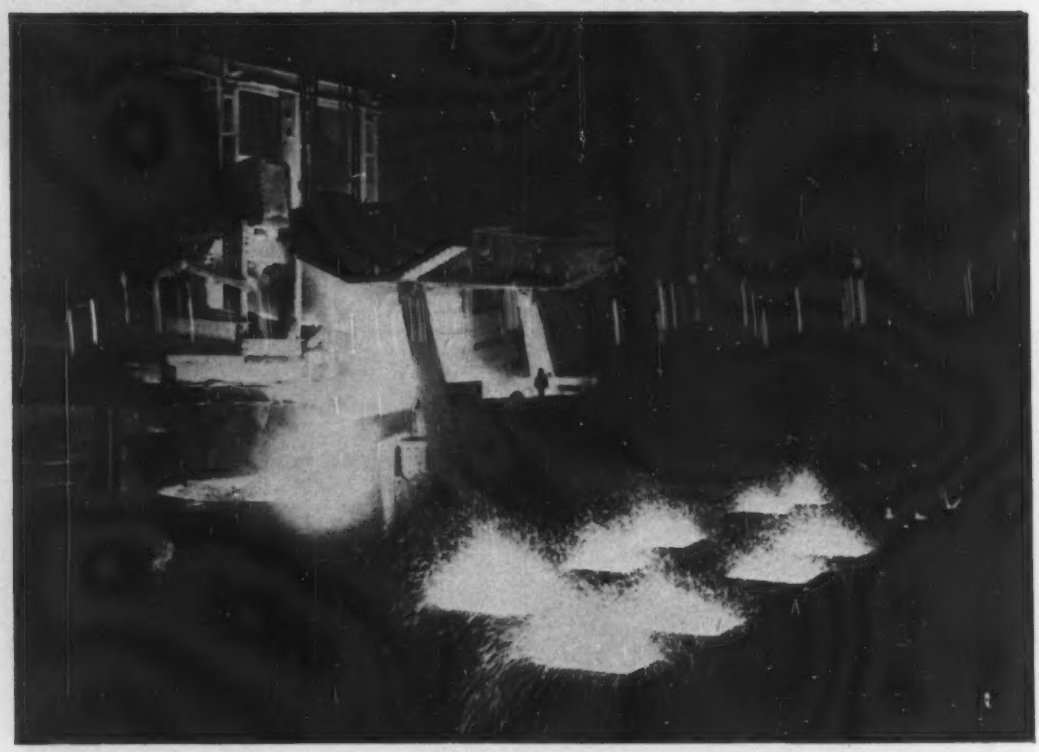
WORKS: IRLAM & WARRINGTON



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Wearing slippers is only one of the engineering applications of Ferobestos—the versatile, asbestos-reinforced plastic material. Here are just a few more of the ways Ferobestos can be used:—

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THE STEEL COMPANY OF WALES LIMITED

The slabbing mill motor room at Abbey Works

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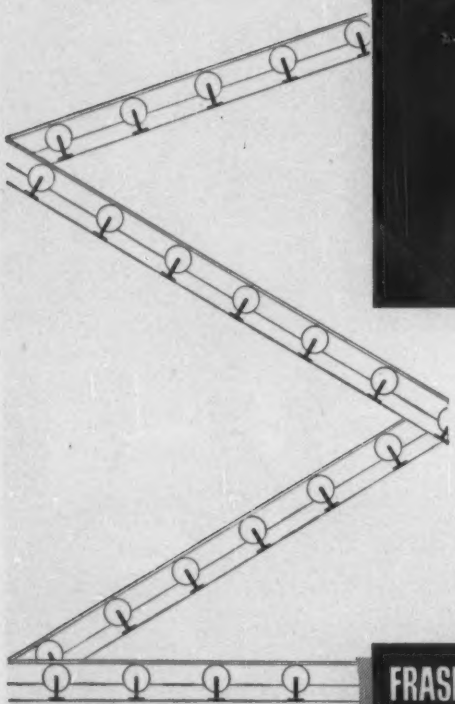

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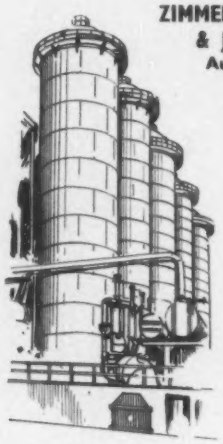
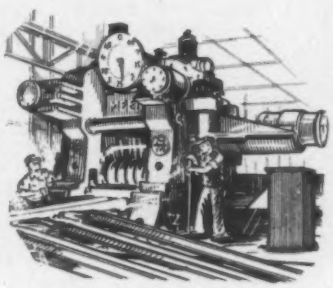


MEER AG Plug Mill



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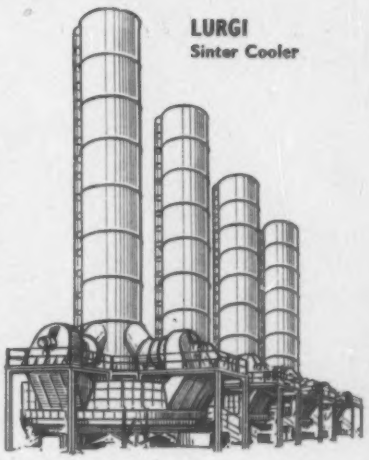

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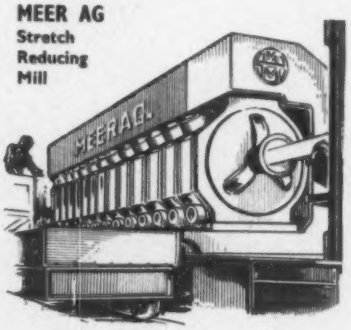

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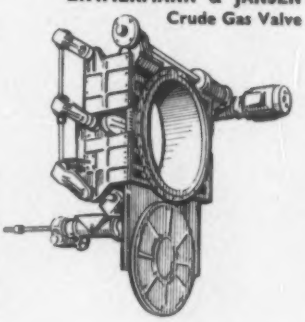

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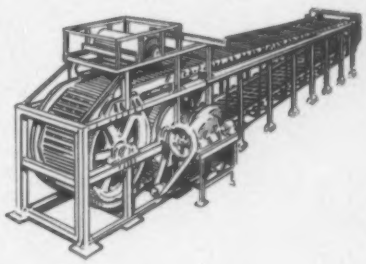

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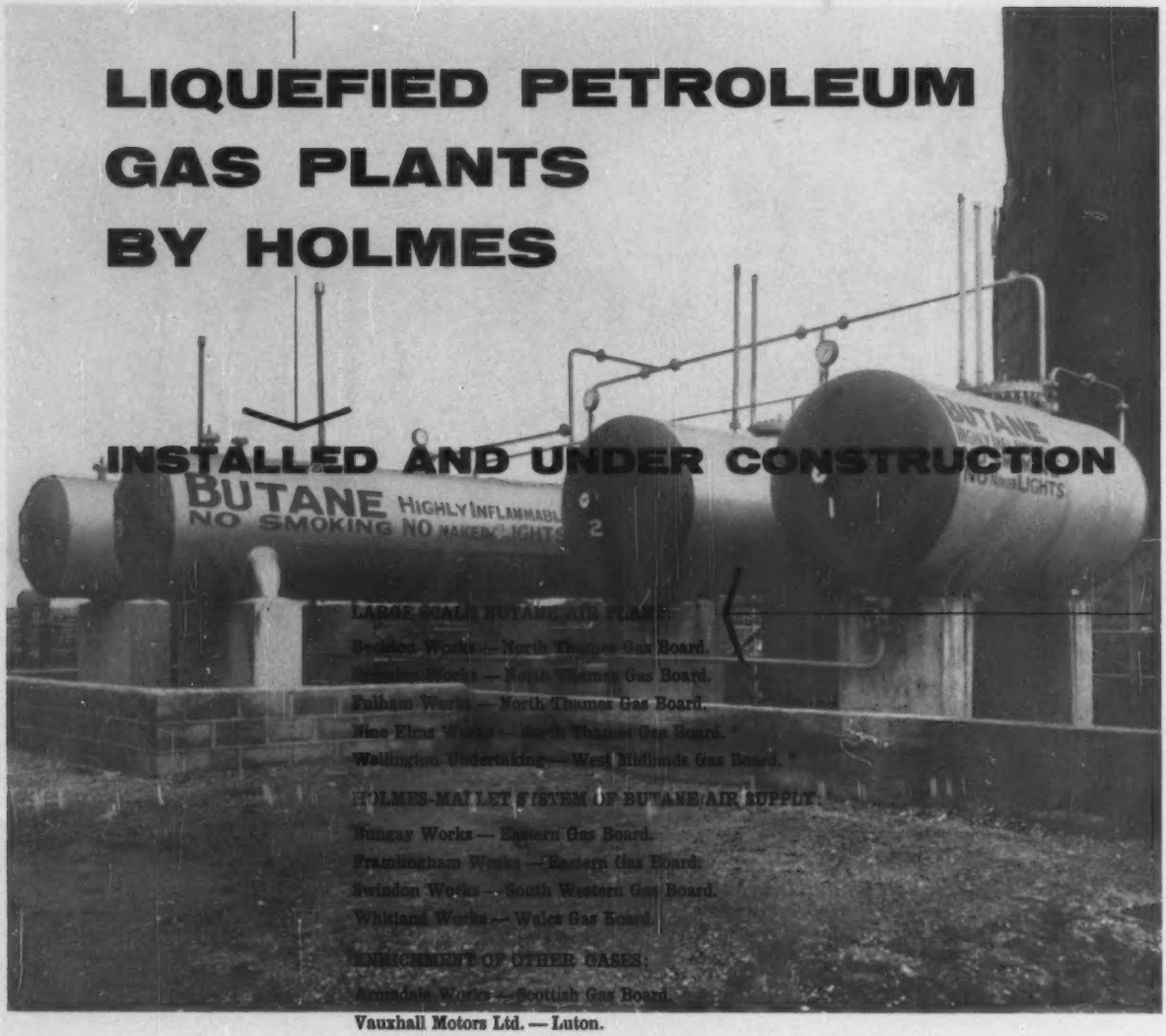

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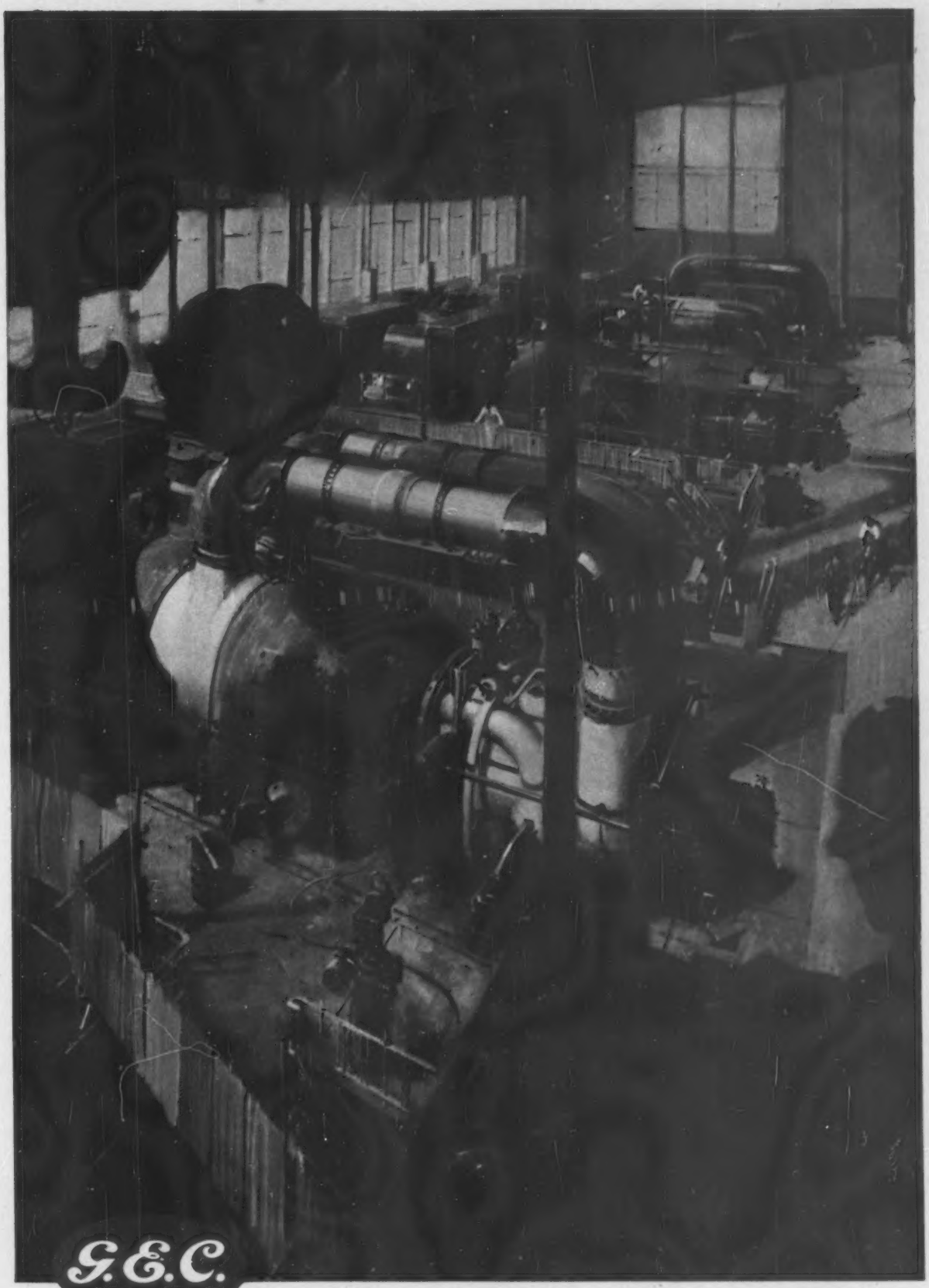

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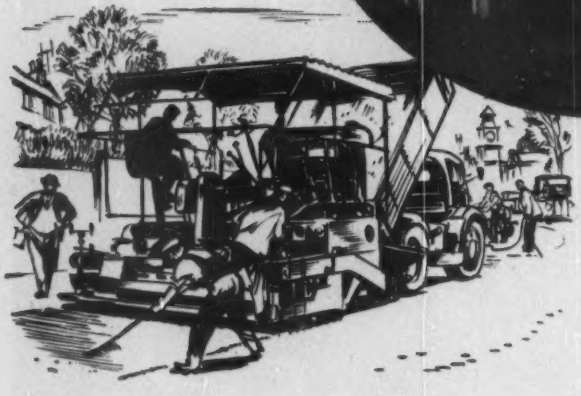

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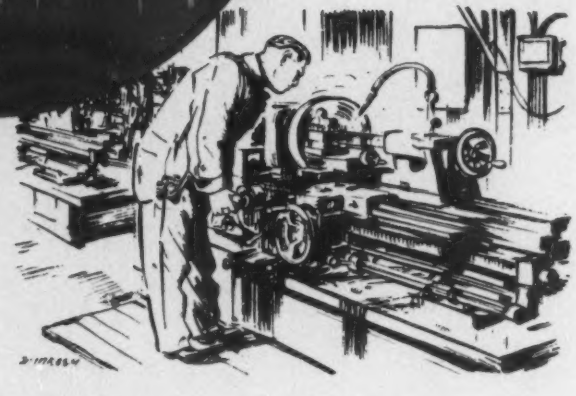

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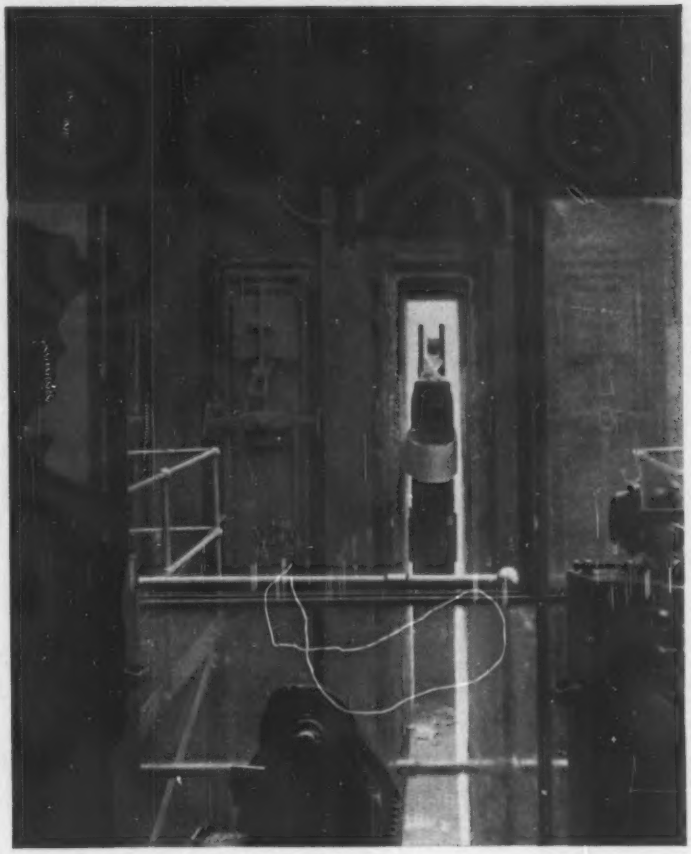

The W-D Gamma Interlock automatically ensures that a coke oven charge cannot be pushed until both doors have been removed and the pusher machine and the coke guide to the coke car correctly aligned with the oven.
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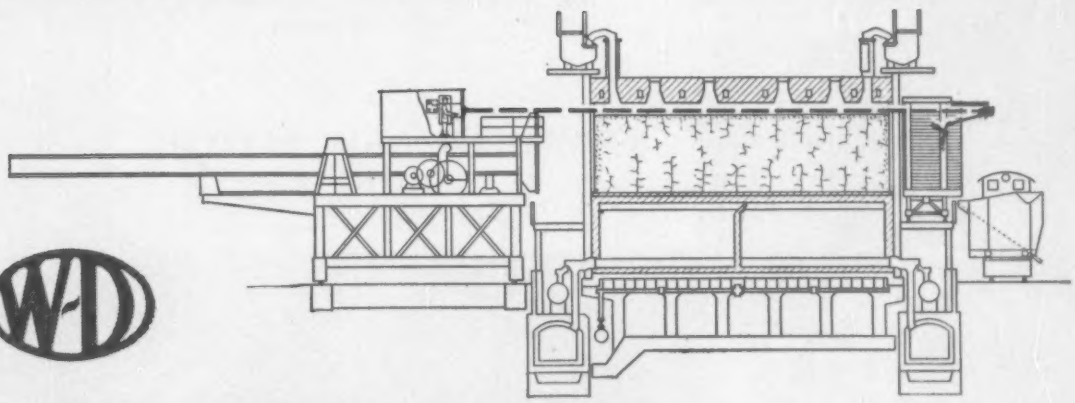
The isotope has an effective life of some years, is very easily and cheaply replaced and is completely safe in operation.
The W-D Gamma Interlock can be incorporated in all new coke oven plants and added to most existing plants.



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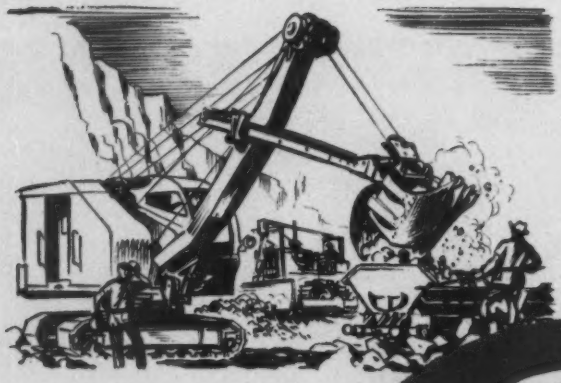

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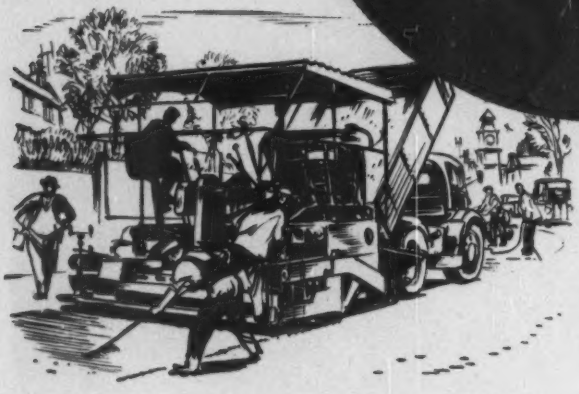

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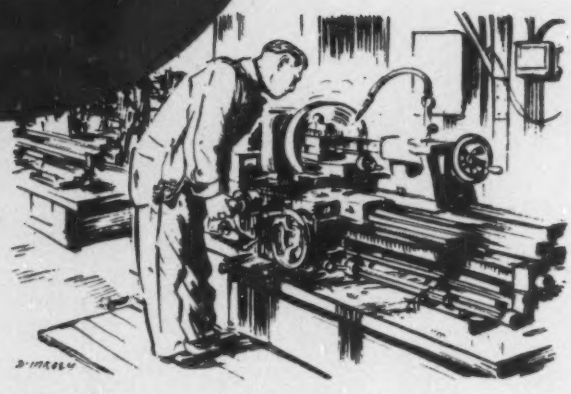

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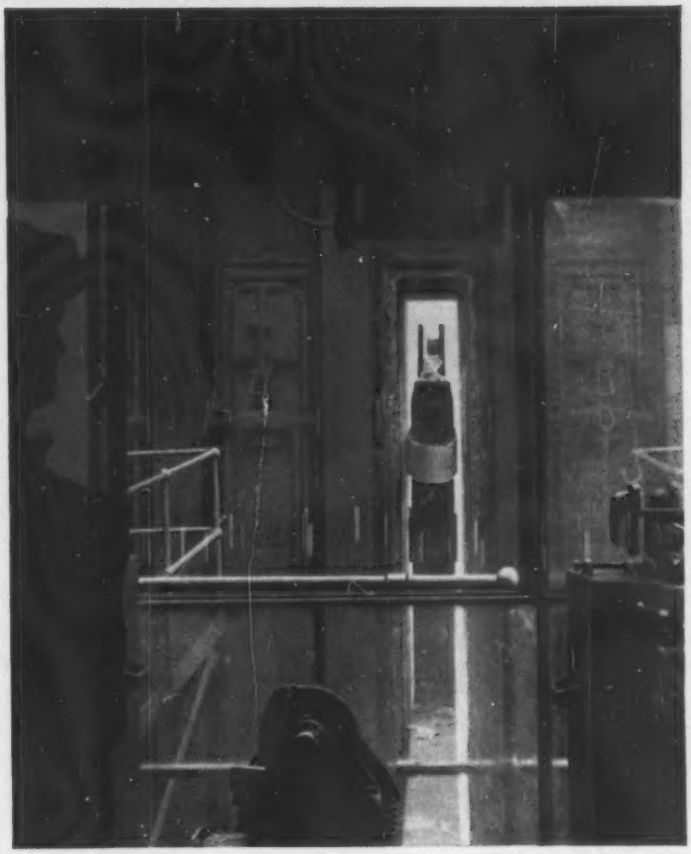

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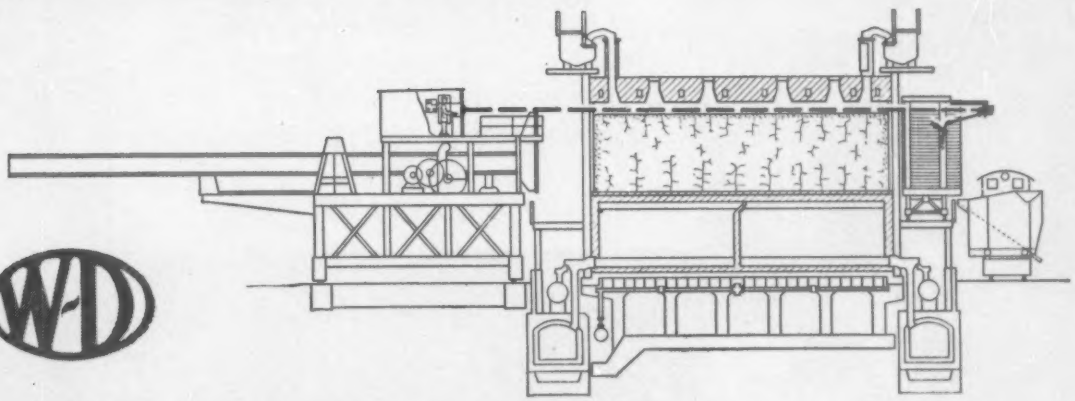

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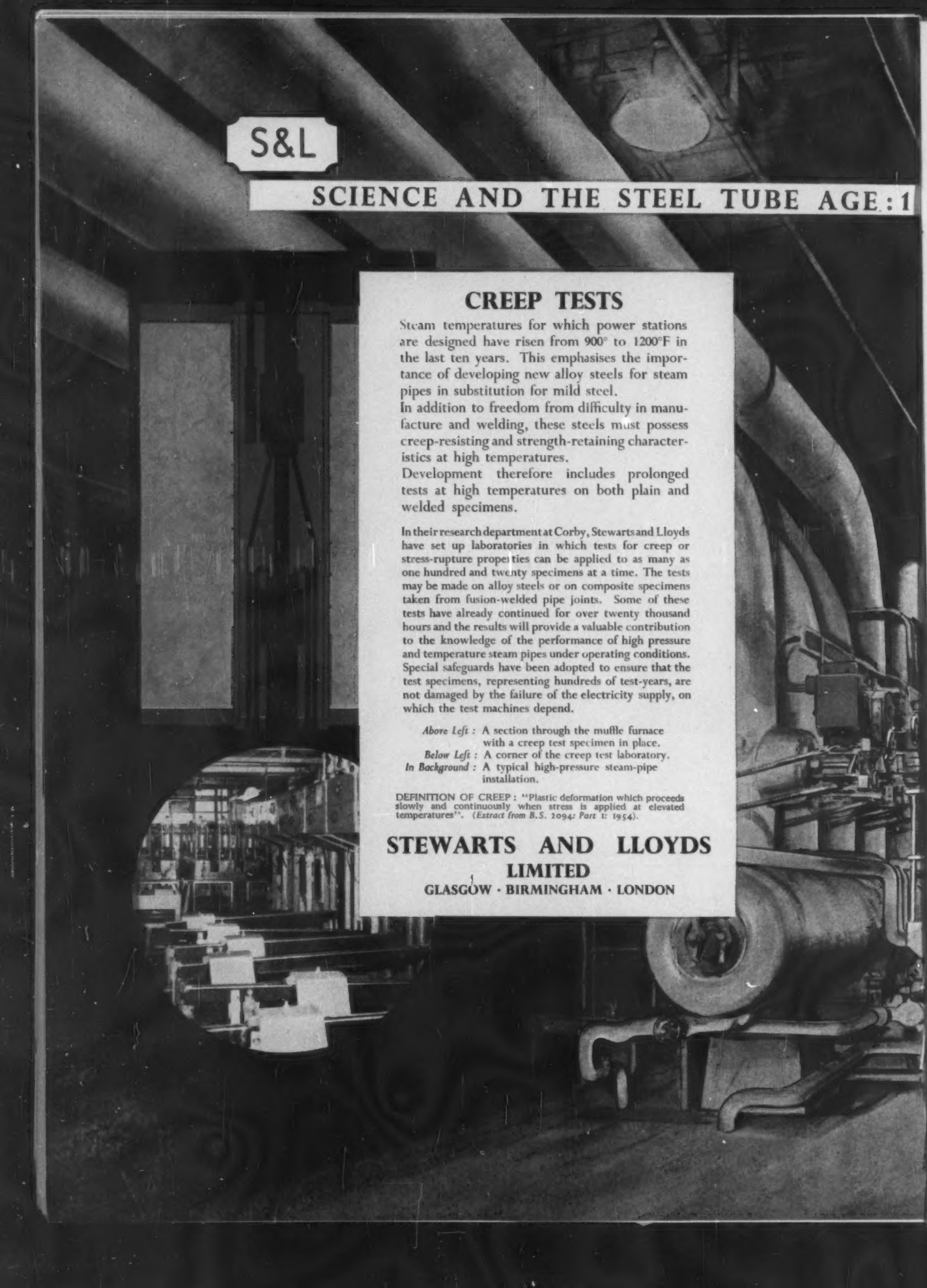

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SCIENCE AND THE STEEL TUBE AGE: 1

CREEP TESTS

Steam temperatures for which power stations are designed have risen from 900° to 1200°F in the last ten years. This emphasises the importance of developing new alloy steels for steam pipes in substitution for mild steel.

In addition to freedom from difficulty in manufacture and welding, these steels must possess creep-resisting and strength-retaining characteristics at high temperatures.

Development therefore includes prolonged tests at high temperatures on both plain and welded specimens.

In their research department at Corby, Stewarts and Lloyds have set up laboratories in which tests for creep or stress-rupture properties can be applied to as many as one hundred and twenty specimens at a time. The tests may be made on alloy steels or on composite specimens taken from fusion-welded pipe joints. Some of these tests have already continued for over twenty thousand hours and the results will provide a valuable contribution to the knowledge of the performance of high pressure and temperature steam pipes under operating conditions. Special safeguards have been adopted to ensure that the test specimens, representing hundreds of test-years, are not damaged by the failure of the electricity supply, on which the test machines depend.

Above Left : A section through the muffle furnace with a creep test specimen in place.
Below Left : A corner of the creep test laboratory.
In Background : A typical high-pressure steam-pipe installation.

DEFINITION OF CREEP : "Plastic deformation which proceeds slowly and continuously when stress is applied at elevated temperatures". (*Extract from B.S. 2094: Part 1: 1954*).

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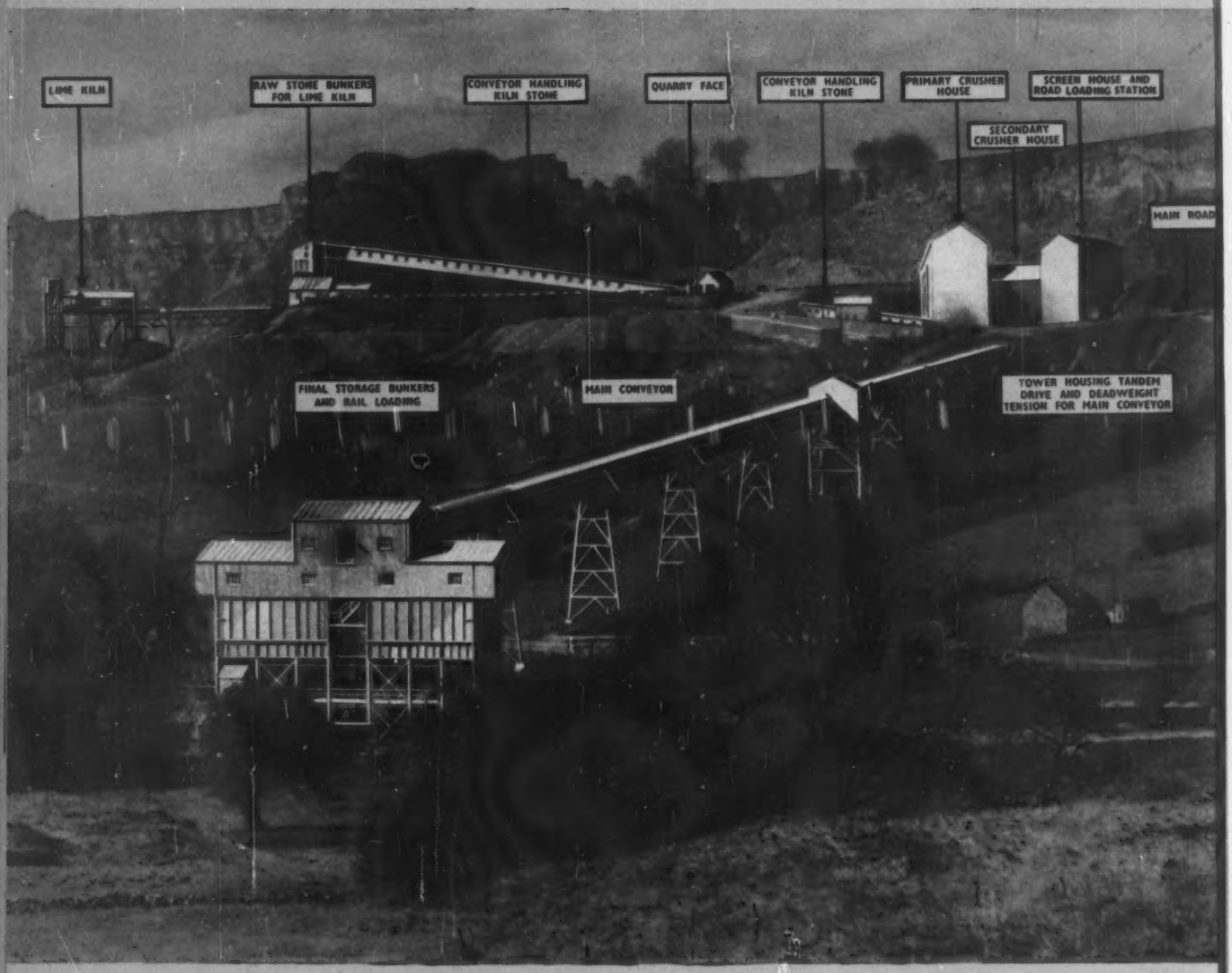
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Professor J. M. KAY, M.A., Ph.D., A.M.I.Mech.E., A.M.I.Chem.E.

JOHN MENZIES KAY was educated at Sherborne School and Trinity Hall, Cambridge. He began his engineering career as an apprentice at the Locomotive Works at Crewe. After wartime service with the Royal Naval Volunteer Reserve, he returned in 1946 to the Engineering Department, Cambridge University, where he carried out research on fluid mechanics with Sir Melvill Jones. In 1948 he joined the staff of the newly formed Department of Chemical Engineering, where he lectured in fluid mechanics and heat and mass transfer.

In 1952 Dr. Kay was appointed Chief Technical Engineer in the Department of Atomic Energy Production (subsequently the United Kingdom Atomic Energy Authority, Industrial Group) at Risley. After a short period with a firm of consulting engineers, he was appointed in 1956 to the Chair of Nuclear Power at the Imperial College of Science and Technology.

Professor Kay delivered a Special Lecture on "The Future Engineering Development of the Gas-Cooled Nuclear Reactor" at the Royal Institution on 24th September, 1957, as part of the Autumn General Meeting of The Iron and Steel Institute. A shortened version of the lecture appears on pp. 3–8 of this issue of the *Journal*.

Professor J. M. Kay, M.A., Ph.D., A.M.I.Mech.E., A.M.I.Chem.E.

PROCEEDINGS OF

THE INSTITUTE

Reports of Council · Meetings · Notices

Autumn General Meeting, 1957

The AUTUMN GENERAL MEETING of THE IRON AND STEEL INSTITUTE was held on Tuesday, 24th September, 1957, at the Offices of the Institute, 4 Grosvenor Gardens, London, S.W.1. The President, Mr. A. H. INGEN-HOUSZ, was in the Chair.

Three Technical Sessions were held, one from 10.45 A.M. to 12.45 P.M., and two from 2.45 to 5.0 P.M. The discussions at these sessions, details of which were given on p. 55 of the September issue, will be reported later in the *Journal*.

MINUTES OF THE PREVIOUS MEETING

The Minutes of the Annual General Meeting held in London on 22nd and 23rd May, 1957, were taken as read and confirmed.

PRESIDENT'S REMARKS

Welcome to Members and Visitors

The **President** (Mr. A. H. Ingen-Housz) extended a welcome to all Members and visitors attending the meeting. He extended a personal welcome to those Members who came from overseas. As one who had often come from overseas to these meetings, he knew from personal experience that these visits to England and the friendly contacts which were made and renewed were useful and gave great pleasure.

The Council had tried to make the Meetings more attractive by holding discussions not only on specialized aspects of the iron and steel industry, but also by introducing a special general evening lecture, to be given that evening by Professor J. M. Kay. It was hoped in this way to attract a greater attendance at meetings, which gave an opportunity not only for various subjects to be dealt with, but also for Members to meet one another, which was important in the development of the industry, particularly in the case of the younger members.

They were happy to learn that a number of members of other Societies which participated in the British Nuclear Energy Conference had accepted invitations to join in the discussion at one of the afternoon sessions that day.

It was customary for the Institute to hold either an Autumn or a Special Meeting each year in a steelmaking district, either in the U.K. or on the Continent, but they were not doing so this year. This decision was justified by the importance of the Symposium on Air and Water Pollution, which was to be opened at Church House on the following day and continued there in December. Nevertheless, he personally regretted the decision. He reassured the meeting that there was no change in policy; plans were far advanced for the meeting in June, 1958, in Belgium and Luxembourg. That meeting would be held in conjunction with the Journées Internationales de Sidérurgie, organized by the Centre National de Recherches Métallurgiques, the Groupement des Industries Sidérurgiques Luxembourgeoises, and the Groupement des Haut Fourneaux et Aciéries Belges, in Liège, Luxembourg, Brussels, and Charleroi. That would be an important and interesting occasion.

Obituary

The Institute had suffered the loss by death of fifteen of its Members. He referred in particular to the loss of two Members of Council. Mr. Arthur Dorman, who died on 8th September, had joined the Institute in 1908, became a Member of Council in 1924 and a Vice-President in 1932, and had served as President from 1944 to 1946. All Members knew of his great love of and devotion to the Institute. Mr. Gerald Steel, C.B.E., who died on 13th September, had joined the Institute in 1942, and became a Member of Council in 1944 and a Vice-President in 1948. He was President-Elect of the British Iron and Steel Federation. He had also been one of the most distinguished Members of The Iron and Steel Institute, and a man from whom the industry had hoped very much.

Activities of the Institute

The work of the Institute was progressing satisfactorily; he was particularly pleased with the high quality of the publications. The Council had been giving attention to the organization of meetings; they wanted to be

certain that facilities offered were those which Members required. Some changes were being made now, and they might be able to suggest further improvements later.

Meetings in 1957

In addition to the Engineers Group Meetings on Air and Water Pollution, an afternoon meeting was being organized in Sheffield on 28th November, in conjunction with the Sheffield Metallurgical Association and the Sheffield Society of Engineers and Metallurgists. On the evening of the same day Professor Paul Bastien would deliver the Tenth Hatfield Memorial Lecture. The arrangements for this were being made by the University of Sheffield.

The Inaugural Meeting of the Powder Metallurgy Group, which was a Joint Group with The Institute of Metals, was to be held at Church House, Westminster, on 4th December.

Translation Service

Dr. Burton, at the Annual Meeting, had drawn attention to the new Translation Service. At the suggestion of B.I.S.R.A. and after consultation with the British Iron and Steel Federation, a number of companies in the steel industry had agreed to pool resources. A good start had been made. The intention was to ensure that a wide range of translations of technical papers was made available to Members of the Institute and of B.I.S.R.A.

Historical

The chief concern of the Institute was properly with the present and the future. All the same, it was fitting that from time to time they should glance backwards and look with new eyes at the work of their predecessors, on the foundation of whose achievements their modern industry was built.

There was to be published later in the year (by Routledge and Kegan Paul Ltd.) a "History of the British Iron and Steel Industry, *c.* 450 B.C. to A.D. 1775," by Dr. H. R. Schubert. Dr. Schubert was known to many of them as the Historical Investigator who contributed notes of exceptional interest to the *Journal*. His history was a work of rare scholarship, and the Council were proud to have been able to facilitate its appearance. They believed that it would prove to be the standard work on the subject. It would be available on preferential terms to Members of the Institute.

The President went on to discuss the centenary of the open-hearth furnace, which was to be celebrated by the Institute in 1963. A full report of his remarks appeared in the November, 1957, issue of the *Journal* (vol. 187, p. 240).

NOMINATION OF PRESIDENT-ELECT

The **President** said that he had great pleasure, on behalf of the Council, in proposing that Mr. C. R. Wheeler, C.B.E. (*Vice-President*) be nominated for election as President, to take office at the Annual General Meeting in 1958, and to serve for one year.

The Institute was fortunate in having such a distinguished President in a year of great importance, in which the Institute would join the Belgian institutes in their international meeting. He felt that the Council and the Institute were to be congratulated on their choice.

Mr. C. R. Wheeler, C.B.E., said that it was a matter pride for a steel man to be nominated as President of so eminent a body as the Institute.

NEW APPOINTMENTS

Honorary Vice-Presidents

The **President** announced that the Council had nominated the following to be Honorary Vice-Presidents, in recognition of the long and distinguished service which they had given. It was hoped that the Institute would long continue to benefit from their wise counsel:

Mr. D. F. Campbell (*Member* 1910; *Member of Council* 1946; *Vice-President* 1954)

Mr. I. F. L. Elliot (*Member* 1924; *Member of Council* 1935; *Vice-President* 1951)

Mr. G. H. Latham (*Member* 1936; *Member of Council* 1940; *Vice-President* 1946).

Member of Council

The **President** announced that the Council had elected Lieutenant-Commander G. W. Wells, R.N. (RETD.), to be an ordinary Member of Council. Commander Wells was a Director and the General Manager of the Appleby-Frodingham Steel Company and a Director of the United Steel Companies Ltd. He was a Past-President of the Lincolnshire Iron and Steel Institute. He had been elected a Member of the Institute in 1945 and had been Chairman of the Reception Committee for the Special Meeting in Scunthorpe in 1955.

AFFILIATED LOCAL SOCIETIES

The **President** announced that the East Midlands Metallurgical Society had become an Affiliated Local Society of the Institute, and that Mr. N. S. Angus, President, had accepted an invitation to become an Honorary Member of Council during his period of office.

There were now thirteen Affiliated Local Societies and, as all Members appreciated, this arrangement for mutual collaboration served a very useful purpose. They all welcomed very heartily the thirteenth member of this important group.

ANNOUNCEMENTS

The **Secretary** (Mr. K. Headlam-Morley) made the following announcements.

Changes on Council

Changes on the Council since the last General Meeting in May, 1957:

Honorary Members of Council

I. *Representing Affiliated Local Societies:*

Mr. Philip A. Green, President of the Leeds Metallurgical Society, to succeed Mr. A. Lenton.

Mr. A. H. Norris, President of the Lincolnshire Iron and Steel Institute, to succeed Mr. C. T. Thomas.

Mr. H. Brooke Freeman, Chairman of the North Wales Metallurgical Society, to succeed Mr. R. L. Willott.

Mr. G. Parkin, President of the Staffordshire Iron and Steel Institute, to succeed Mr. A. Biddulph.

II. *Representing The West of Scotland Iron and Steel Institute:*

Dr. H. Harris, President, to succeed Mr. S. Thomson (Member of Council).

Retiring Members of Council:

The following were due to retire at the next Annual General Meeting and were eligible for re-election:

Vice-Presidents: Mr. W. F. Cartwright, Sir Charles Goodeve, Mr. N. H. Rollason.

Members of Council: Dr. J. W. Jenkin, Mr. F. H. Saniter, Mr. T. Jolly, Mr. R. A. Hacking, and Mr. W. C. Bell.

Andrew Carnegie Scholarships

The following Andrew Carnegie Scholarships had been awarded since the last General Meeting:

I. M. Davidson (Liverpool University): £300, to assist research on the activity of ferrous oxide in silicate slags.

J. C. Humphreys (Liverpool University): £300, to assist research on carbide constituents in iron–carbon–silicon alloys.

T. Gladman (Sheffield University): £400, to assist research on the effect of hydrogen on transformations in alloy steels.

Meetings in 1958

The *Annual General Meeting* would be held in London on Wednesday and Thursday, 7th and 8th May, and the Dinner for Members on Wednesday, 7th May.

The *Special Meeting in Belgium and Luxembourg* was being held from 18th to 28th June.

The *Autumn General Meeting* would be held in London on Wednesday and Thursday, 26th and 27th November.

ELECTION OF MEMBERS

Dr. **W. A. Archibald** and Dr. **B. G. Baldwin**, the scrutineers of the ballot, reported that the following had been elected:

Members

Basu, Anil Chandra, B.SC., L.I.M. (Rourkella, Orissa, India); **Boddye**, Eric Tatton, B.A. (CANTAB.) (Port Talbot); **Busch**, Mary J. (Mrs.), B.S., A.B. (Coatesville, Pa., U.S.A.); **Cameron**, Donald Ian, B.A. (Newcastle, N.S.W., Australia); **Clegg**, Colin (Batley); **Corbett**, Robert B., PH.D., M.S. (Philadelphia, Pa., U.S.A.); **Cox**, Merrill, B.S. (Cleveland, Ohio, U.S.A.); **Craig**, George Herbert, B.S. (East Chicago, Ind., U.S.A.); **Cross**, Albert Henry Bantiff, PH.D., B.MET., F.I.M., F.I.CERAM. (Sheffield); **Dawance**, Victor (Flemalle-Haute, Belgium); **Deshpande**, D. L., M.SC., M.I.MECH.E., M.I.PROD.E. (Dhanbad, Bihar, India); **Durnford**, John, A.M.I.MECH.E. (Renishaw, near Sheffield); **Fairlie**, James McLachlan, M.A. (London); **Funk**, Charles R., B.S. (Latrobe, Pa., U.S.A.); **Gerhold**, Ernest Alfred (Chobham); **Godber**, Frank (Redhill); **Gosse**, Edmund Barr, M.A. (Newcastle, N.S.W., Australia); **Grayson**, Cyril Leake (Sheffield); **Hamilton**, Peter (London); **Hoskin**, Waldemar A. P., M.I.GAS E., M.I.CHEM.E., M.INST.F. (Barnsley); **Jones**, Stanley Raymond Dennis, L.I.M. (Brierley Hill); **Jones**, Thomas Edward Malcolm, B.SC. (Thornaby-on-Tees); **Joyce**, Douglas (Sault Ste Marie, Ont., Canada); **King**, Harold Arthur, L.I.M. (Port Melbourne, Victoria, Australia); **King**, Hubert Wylam, PH.D., B.SC. (Birmingham); **Kirk**, Frederick Arthur, A.MET., A.I.M. (Sheffield); **Kövesi**, Paul, D.MET. (Sheffield); **Lamb**, Roger Maxwell, B.SC.(MET.), A.I.M. (Steurbridge); **Leroy**, Pierre J. (St.-Germain-en-Laye, France); **Leung**, Laiyuen (Hong Kong); **Lysaght**, John Charles Fettiplace (Port Kembla, N.S.W., Australia); **McCusker**, Neal (Sydney, N.S.W., Australia); **Mackin**, Brian Eugene (Middlesbrough); **Madsen**, Alan Rowland (Hebburn-on-Tyne); **Notini**, Ulf Gunnar (Stockholm, Sweden); **O'Connor**, Terence, B.ENG., A.M.I.C.E. (Thornaby-on-Tees); **Parbury**, Philip Kingsmill (Wollongong, N.S.W., Australia); **Pope**, Jack Geoffrey Colbran (London); **Rees**, Malcolm Gwilym Dewi, B.SC. (Rotherham); **Richmond**, F. M., M.S. (MET.ENG.) (Bridgeville, Pa., U.S.A.); **Robredo Galguera**, Raimundo (Aviles, Spain); **Sarma**, Jayanti Sita Rama, B.SC. (Kakinada, India); **Sayles**, Eric, B.SC.(ENG.), M.I.MECH.E. (London); **Shaw**, Derrick Wilmot, B.MET., A.I.M. (Sheffield); **Sims**, Leslie William, B.SC. (Dundee); **Steel**, Gerald Kirton, A.C.T., D.I.C., GRAD.I.E.E. (London); **Stirland**, Clive (Middlesbrough); **Thomas**, Patrick Muirhead, D.S.O., T.D., B.A. (Glasgow); **Toseland**, Michael Frank (Corby); **Tulloch**, John Trail Garland, A.I.M. (Neston); **Urquhart**, Robert Elliott, Major-General, C.B., D.S.O. (Glasgow); **Wagstaff**, Peter, L.I.M. (Rotherham); **Walker**, Harry, G.I.MECH.E. (Middlesbrough); **Weare**, Arthur Thomas (Nuneaton); **Williams**, Robert C., B.S. (Columbus, Ohio, U.S.A.); **Wilson**, Raymond (London).

Associate Members

Eid, Abdelaziz (Berlin, Germany); **Lehan**, Margaret Harriet (London); **Padmanabhan**, T. A., B.SC.(MET.ENG.) (London); **Roberts**, John (Swansea); **Suprinick**, Harry, B.S.(MECH.ENG.), B.S.(MET.ENG.) (Bethlehem, Pa., U.S.A.); **Tidman**, Maurice Danny (Coventry); **Towers**, Trevor Arthur, A.M.I.B.F., L.I.M. (Doncaster).

The **President** declared these candidates to be duly elected. They numbered 63, and the total membership of the Institute was now 5003.

Future Engineering Development of the Gas-cooled Nuclear Reactor

By J. M. Kay, M.A., Ph.D., A.M.I.Mech.E., A.M.I.Chem.E.

SYNOPSIS

The paper opens with a review of the basic technology of the gas-cooled graphite-moderated reactor of the Calder Hall type. It is shown that the present commercial power-producing reactor designs are based on the use of (1) a larger size of core, (2) higher average heat rating in MW per ton of fuel, (3) longer irradiation, and (4) slightly higher temperatures. The range of development, using materials similar to those employed at Calder Hall, is discussed in some detail. Finally, the implications of changes in materials and in basic reactor technology are analysed. 1504

THE FIRST detailed investigation into the possibility of a large-scale nuclear power programme was carried out at Risley in 1953. It was realized that the programme would have to be based on the use of *natural uranium* at least for the first decade. It was also believed that the main factor determining the scale and timing of the programme would be the actual physical shortage of coal and oil. It seemed that, for the United Kingdom at any rate, with the steadily growing demand for electricity on the one hand and the continuing inability to produce more coal on the other hand, the need for nuclear power on a large scale would come very suddenly and very quickly. These considerations pointed towards the gas-cooled graphite-moderated reactor as the foundation for any nuclear power programme in Great

This is a condensed version of the Special Lecture delivered at the Royal Institution on 24th September, 1957, as part of the Institute's Autumn General Meeting.

Dr. Kay is Professor of Nuclear Power at Imperial College, South Kensington.

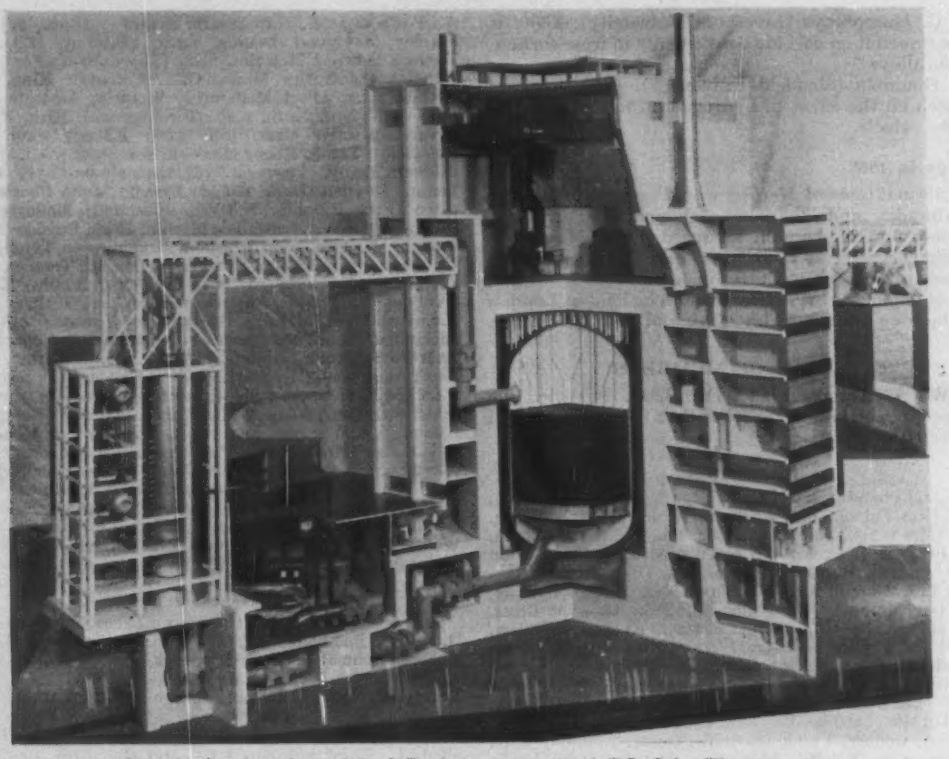

Fig. 1—Sectioned model of Berkeley reactor (A.E.I.–John Thompson)

Britain. This was the only type of nuclear reactor which could be regarded as a reliable engineering proposition and at the same time could be fuelled with natural uranium.

The design and construction of the plutonium-producing reactors at Calder Hall provided the detailed engineering basis for the first stage of the power reactor programme. A full account of the engineering features of these reactors has been given in the proceedings of the "Symposium on the Calder Works Nuclear Power Plant," published in Volume 2 of the *Journal of the British Nuclear Energy Conference*. It must be emphasized, however, that the design of the Calder Hall plant was optimized for plutonium production and also that the required period of irradiation of the fuel elements was relatively short.

For the first round of the civil power programme it was decided to retain the basic physics and technology of the Calder Hall design. For a commercial power-producing reactor, however, it is essential to achieve the following:

(1) Larger size of core
(2) Higher average heat rating in megawatts per ton of fuel
(3) Longer irradiation (2500–3000 MWD per ton)
(4) Higher temperatures.

Consider first of all the problem of increasing the size of the reactor core, which is probably the most important development of all at the present stage. It is certainly possible to construct a cylindrical pressure vessel of about 50 ft diameter using 3-in. thick steel plate, compared with the Calder Hall design of 37 ft diameter using 2-in. thick plate. It should then be possible to accommodate an active core of 40–42-ft diameter, compared with the 31-ft diameter at Calder, representing an increase of about 35% in diameter. It should also be possible to increase the channel length or height of the active core, although not in the same proportion, because of the problem of the pressure drop in the channels and the desire to avoid an excessive range of temperature between gas inlet and outlet. As a reasonable compromise we might choose an active core height of, say, 24 or 25 ft, representing an increase of about 15% on the Calder figure. We thus arrive at a reactor core having an active volume approximately twice that of the Calder design. Taking the same lattice geometry and fuel-rod diameter as at Calder, and noting that the Calder reactors each contain a charge of 130 tons of uranium, we arrive at a tonnage of uranium in the improved design of about 250–260 tons.

The larger size of core will permit the use of a greater degree of flattening of the neutron flux. This will result in a higher average to maximum ratio for the fuel or channel heat rating. A radial average to maximum ratio of about 0·8 would not be unreasonable. This will in turn permit the raising of the average fuel heat rating by a useful amount. Taken in conjunction with a slight advance in the permissible fuel-element surface temperature, say, from 410° to 430° C, and with minor modifications to the design of the can to give a slightly improved heat-transfer

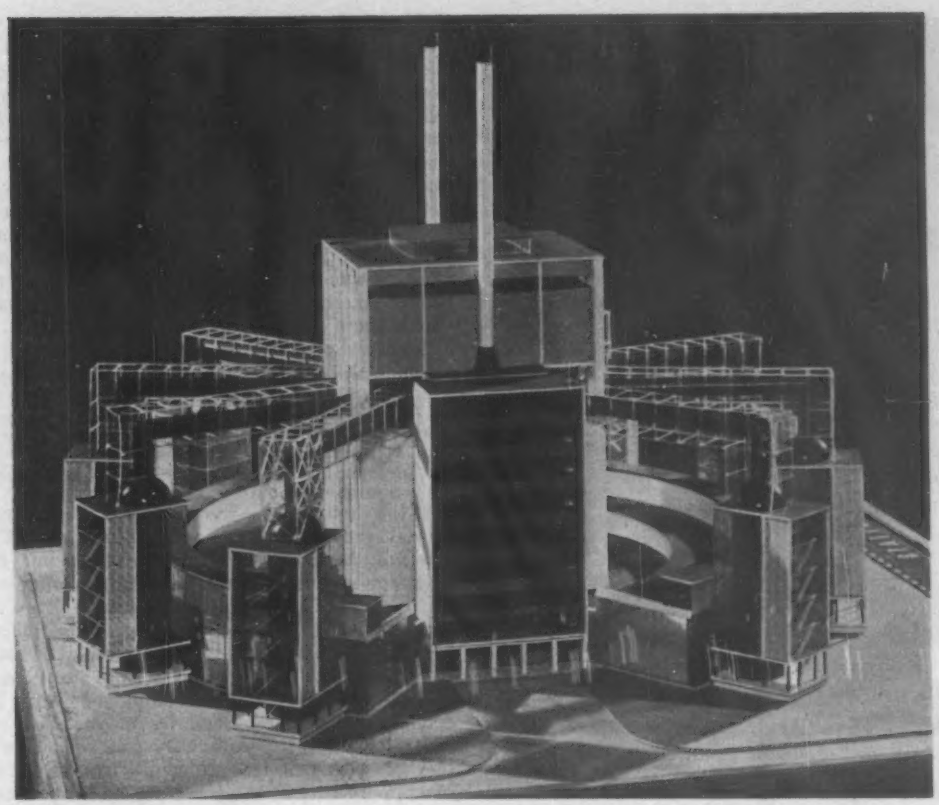

Fig. 2—Model of complete reactor building for the Berkeley station

surface, it should be possible to step up the heat rating of the fuel by about 50% from the Calder figure of 1·4 MW/ton.

It will therefore be reasonable to take 2·1 MW/ton as a typical figure for the average heat rating in today's design. With 260 tons of uranium in the core we will thus have a heat output of about 560 MW and, taking an overall thermal efficiency of about 27%, we should have an *electrical output of about 150 MW* from one reactor.

It is important to appreciate that this advance by a factor of more than three on the Calder Hall output is almost entirely a matter of engineering design. We are not using any essentially different materials and we are not altering the basic physics of the reactor in any way; indeed the reactor physicist has little more to do than calculate the extra amount of flattening required and its disposition in the core. These developments to larger sizes and higher average heat ratings, listed above as items (1) and (2), resulting in an electrical output of the order of 150 MW per reactor, have already been achieved in the first of the commercial designs now under construction at Berkeley, Bradwell, and Hunterston.

It is also of the greatest importance, however, to achieve longer irradiation for the fuel. This development, listed above as item (3), calls for great ingenuity in the design. Perhaps the best policy here is to provide individual support for the fuel elements, and at least two of the first commercial designs incorporate this feature. Also, for power-station operation it is necessary to change fuel elements while continuing to operate the reactor under load. With the larger sizes of core under consideration having approximately 3000 channels, with an average heat rating of about 2·1 MW per ton of fuel, and with an irradiation level of 2500–3000 MWD per ton, it will be necessary to re-fuel about two channels every day. It may also be worthwhile to carry out some reshuffling of the fuel elements in the reactor in order to achieve a more uniform level of irradiation throughout the core. Fuel changing should thus be regarded as an almost continuous routine process. All the present British commercial designs of gas-cooled reactor incorporate arrangements for normal routine fuel changing under load. This may well prove in time to be the biggest single selling point of all in favour of the gas-cooled reactor. No other type of nuclear reactor at present envisaged as a serious engineering project can compete on this particular feature. All the projected liquid-cooled reactors suffer from a grave disadvantage on this point.

The final item listed above concerns the development towards higher temperatures. In spite of the publicity given to this, however, the advance towards higher temperature is probably the least important of the current developments. There is no special merit in high temperature for its own sake. The

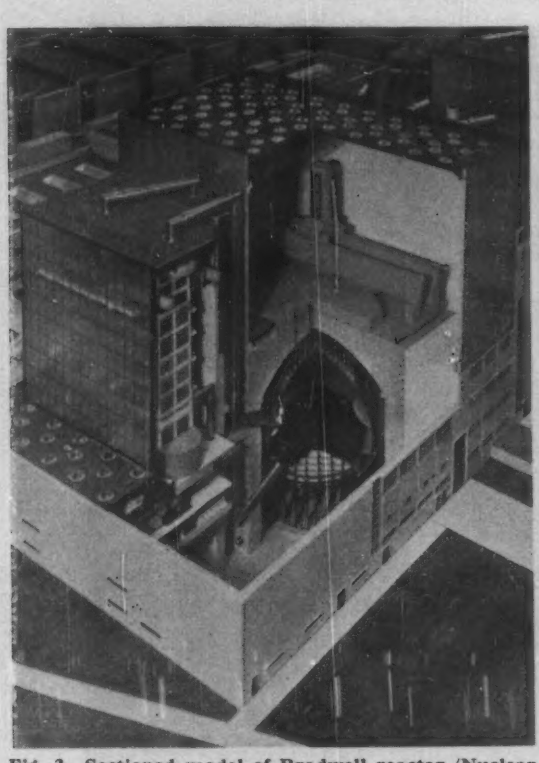

Fig. 3—Sectioned model of Bradwell reactor (Nuclear Power Plant Company)

higher thermal efficiency resulting from higher operating temperature may easily be offset by a reduction in reliability of the plant or a decrease in the average permissible fuel-element life. It will certainly be necessary to proceed very carefully and very cautiously in this matter.

It may be of interest to consider how far the present basic design of gas-cooled reactor can be pressed without introducing any radical change in the materials of construction. Keeping to the existing type of fuel element using a magnesium alloy can, but with individual support for each fuel element in the channel, it should be possible to advance to a permissible surface temperature of 450° C, and possibly as far as 475° C, but this would appear to be the absolute practical limit. Some further improvement in heat-transfer surface is also certainly possible. Taken in conjunction with a still larger size of core, it should be possible to count on a further advance in average heat rating, perhaps to a figure in the range of 2·5–2·8 MW/ton. A specific heat rating twice that of Calder is probably the practical limit using solid metal rods and magnesium alloy cans.

If the fuel element represents the first and biggest problem, the pressure vessel certainly makes the next outstanding demand on engineering skill. We have already noted the importance of size, but one hesitates to go much beyond a 70-ft dia. spherical shell using steel plate of about 3 in. thickness. By careful design, however, it should be possible to accommodate between 300 and 400 tons of uranium fuel in the core. Taking 350 tons as a typical figure, and with an average heat rating of 2·5–2·6 MW per ton of fuel, the heat output from a single reactor of this enlarged design should be about 900 MW. With an overall efficiency of 28%, the electrical output would be approximately 250 MW from a single reactor. A plant of this size constructed at a capital cost of about £110 per kilowatt would be immediately competitive with any coal-fired power station in the United Kingdom, and would also be a fully commercial proposition in most Western European countries. It cannot be too strongly emphasized that the gas-cooled reactor is the only type of nuclear plant for which there is an immediate economic case.

A special problem, of interest to the steel industry, arises in the choice of material for the pressure vessel. There are at present two main alternatives:

(*a*) To use a boiler-quality mild steel, silicon-killed and normalized, with special acceptance tests

(*b*) To use a steel of enhanced notch ductility having a high manganese/carbon ratio, with grain controlling by aluminium, and with normalizing.

If the first choice is adopted, it is necessary to take special precautions against the danger of brittle fracture, particularly during construction. If, however, the second choice is adopted in order to avoid the dangers of brittle fracture, some sacrifice in creep strength is involved. To maintain the temperature of the steel shell at a level below that at which trouble might be experienced from creep, a double skin construction can be employed with internal cooling of the outer shell by means of a suitably controlled flow of cool CO_2 gas. Another major pressure-vessel design problem arises in the method of support of the reactor core, and the method of transmitting the load to the foundations, whether by means of a rocking-column type of support or by means of a continuous supporting skirt.

Further developments are being actively pursued at the present time in the possible use of low-alloy steels and in the matter of heat-treatment of the steel. It is always necessary to keep in mind the essential requirement of good weldability under site conditions, together with the additional requirements of good notch ductility and adequate creep strength.

Having noted the range of development of the 'conventional' gas-cooled reactor from Calder Hall to Berkeley (Figs. 1 and 2), Bradwell (Fig. 3), Hunterston (Fig. 4), Hinkley Point (Fig. 5), and perhaps a little way beyond, it is of interest to consider what may be the next move in design. The limitations of the magnesium alloy canning material have already been referred to. Of the possible alternative materials, beryllium is at present favoured owing to its good nuclear properties, high melting point (1284° C), compatibility with uranium, and reasonably good mechanical properties. It is, however, extremely expensive and difficult to fabricate. If beryllium canning was simply substituted for the magnesium alloy canning in the Calder type of element, only a small gain in temperature would be possible because of the limit set by the central uranium temperature with the $\alpha \rightarrow \beta$ transition at 660° C. In other words, with the Calder type of element one would not be using the beryllium to full advantage and the additional cost would not be justified.

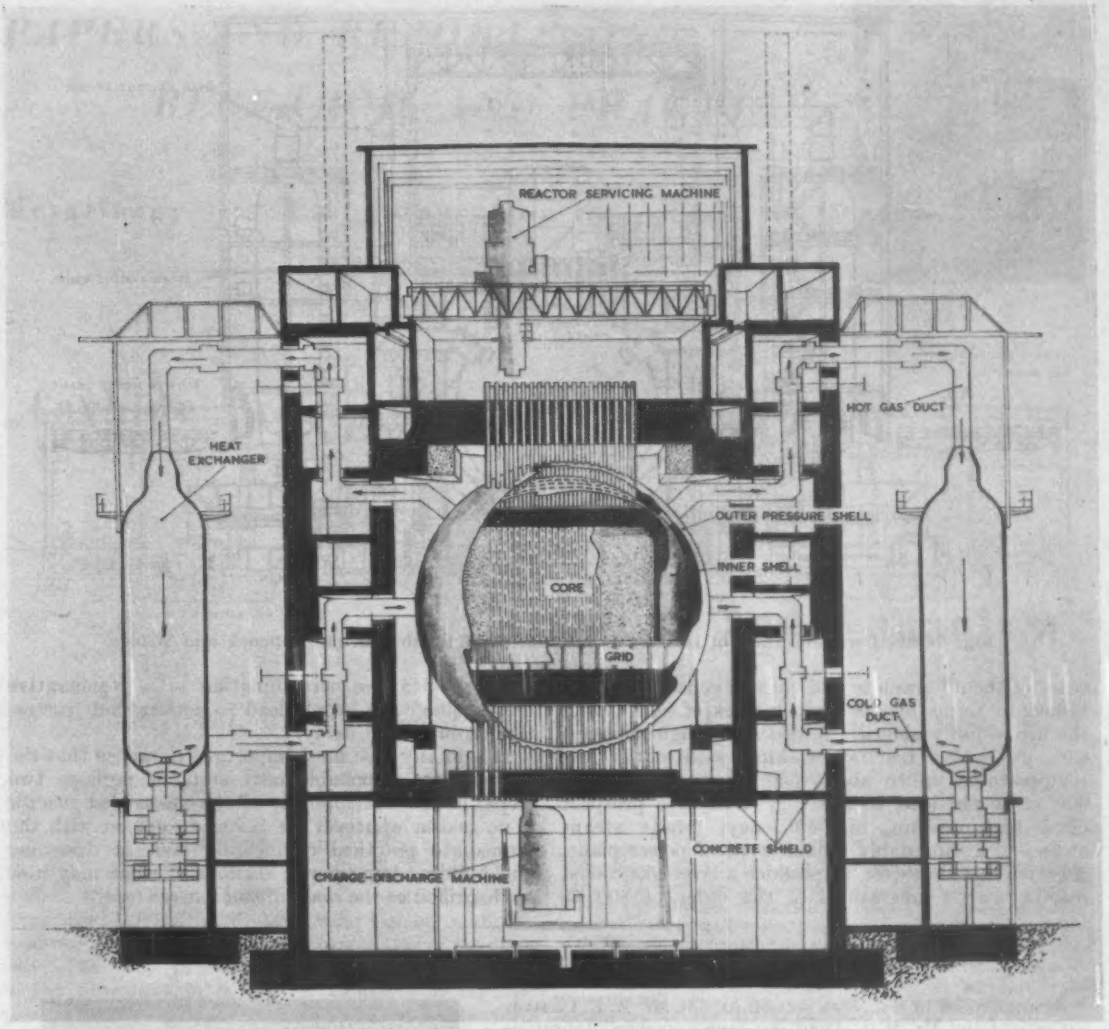

Fig. 4—Sectional elevation of Hunterston reactor (G.E.C.–Simon Carves)

There are two possibilities for getting the best use from beryllium:

(*a*) To use a thin section for the uranium, e.g. a tube, a cluster of small-diameter rods, or a group of thin plates in each channel

(*b*) To use uranium oxide or carbide in place of uranium metal as the fuel.

Either of these solutions, however, would involve slight enrichment of the fuel. It would then be necessary to achieve both a higher average specific-heat rating and a higher level of irradiation to justify the extra cost of both enrichment and the use of beryllium cans. One is thus driven to a quite different basic type of gas-cooled reactor. In making one change we are forced to make several other changes.

One can thus see the possibility of a series of steps in the engineering of the gas-cooled reactor, a kind of discontinuous spectrum. There is a definite range of development within each band of the spectrum. We are at present in the first band, characterized by natural uranium, metal rods of approximately 1 in. dia., magnesium alloy cans, 8-in. lattice pitch, etc. Within this first band the power output from a single reactor has already advanced from the 42 MW of Calder Hall to a figure of 250 MW in the Hinkley Point design. Some further development within this band is certainly possible and it may be expected that a very large number of power reactors of this basic type will be constructed during the next ten years.

The second band of the spectrum is now visible, at least as a distinct possibility, and the general opinion is that this will be characterized by the use of slight enrichment of the fuel, an improved canning material (possibly beryllium), and the use of either thin metal rods or uranium oxide. A third band suggested as a further possibility would involve the elimination of metal parts from the reactor core and the use of an all-graphite and carbide structure, the so-called ' high-temperature gas-cooled reactor '.

It is perhaps unfortunate that some of the advo-

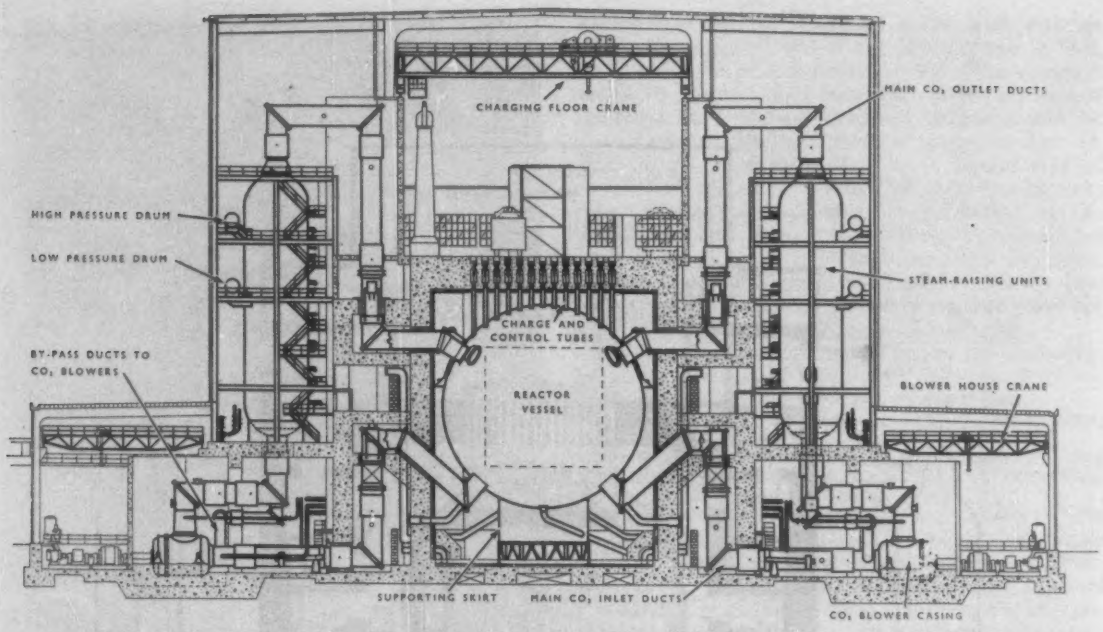

Fig. 5—Sectional elevation of Hinkley Point reactor (English Electric–Babcock and Wilcox

cates of the all-graphite and carbide conception have talked in terms of gas temperatures of 800° C and the use of gas turbines. A *moderately* high-temperature gas-cooled reactor, working with outlet gas temperatures up to about 550° C or at the most 600° C, would lead to the very attractive prospect of a high-pressure, high-efficiency, reheat steam cycle and a thoroughly reliable type of power plant. Any attempt, however, to produce a large gas-cooled reactor with temperatures of the order of 800° C, coupled with the contemplation of a regenerative gas-turbine cycle, would lead to nothing but frustration, trouble and delay.

It is in any case most important to realize that the existence of a possible next step, or perhaps two steps, in the development of the gas-cooled reactor is no reason whatever for failing to get on with the immediate practical engineering task of designing and building large power stations of what may now be described as the *conventional nuclear type*.

Appointment of Librarian

As announced in the News section (p. 63), Mr. A. E. Chattin has retired and Mr. M. L. Pearl has been appointed Librarian and Head of the Information Service.

Mr. Pearl was born in 1914. He received industrial and managerial training in the engineering industry and worked for a number of companies. After the war he undertook a study of scientific and technical education which he ultimately presented as a thesis for the Oxford University Diploma in Economics and Political Science. He also wrote a number of articles for "Chambers' Encyclopaedia" and other works. Following on these and related studies, he was awarded a State Scholarship to The Queen's College, Oxford, where he read politics, philosophy, and economics. On graduating in 1949 he was awarded a four-year training bursary at Nuffield College, Oxford, where he taught economic organization and history to undergraduates and carried out research on various historical and bibliographical studies, one of which, a full-length work on William Cobbett, was published in 1952 by the Oxford University Press.

In 1953 he joined the Information Section of the British Iron and Steel Research Association as a Senior Scientific Officer and began a three-year study of the flow of technical information in the iron and steel industry, which is being prepared for publication. For the past year Mr. Pearl has been Assistant to the Head of the Development and Steel User Section.

PAPERS AND REPORTS ON
RESEARCH AND PRACTICE

Metallurgy · Plant Operation · Research

Carbide Precipitation in Several Steels containing Chromium and Vanadium

By Arun K. Seal, B.Sc., B.Eng., Ph.D., and R. W. K. Honeycombe, M.Sc., Ph.D.

SYNOPSIS

The tempering of several steels with the basic composition 0·2% carbon, 9% chromium has been studied using electron microscopic, X-ray, and electron diffraction methods. The maintenance of hardness in the range 250–400° C is shown to result from the stability of the fine cementite precipitate, a consequence of the high chromium content of the steels. The examination of extraction replicas in the electron microscope shows that between 400° and 550° C the cementite redissolves in the ferrite and Cr_7C_3 is separately nucleated initially as a very fine precipitate (< 50 Å). The tempering behaviour in this range is markedly altered by small additions (0·38–1%) of vanadium, to the extent of forming a secondary hardening peak absent in the plain chromium steel. The vanadium is shown to reduce the tendency of the Cr_7C_3 precipitate to coarsen.

The transformation $Cr_7C_3 \rightarrow Cr_{23}C_6$ appears to occur *in situ* and not by separate nucleation.

Experiments with a 1% vanadium steel in which V_4C_3 precipitates indicate that the greater secondary hardening observed is due in part to the slower coalescence of this carbide, but the degree of registry of the carbide with the matrix must also be significant. 1398

Introduction

IN THE LAST DECADE, the tempering of plain carbon steels has received much attention, and in particular the work of Averbach, Cohen, and co-workers[1,2,3] has clearly defined three stages of tempering. The first which occurs up to about 200° C is the precipitation of the hexagonal iron carbide phase and the formation of low-carbon martensite, while the second is the decomposition of retained austenite in the range 200–300° C. Finally, cementite is precipitated and gradually coarsens. In alloy steels the same phenomena take place, but in many cases a fourth stage follows, namely, the replacement of cementite by one or more alloy carbides. This fourth stage is of particular practical interest for it frequently gives rise to secondary hardening, and enhances high-temperature creep properties.

As the present paper is primarily concerned with chromium steels, it is relevant to review recent findings in similar steels. X-ray examination of carbide extracts from tempered chromium steels has shown that Cr_7C_3 gradually replaces Fe_3C when the tempering temperature reaches 450–500° C. Balluffi, Cohen, and Averbach[1] have examined this transformation in steels containing up to 4% chromium by dilatometric, magnetic, X-ray, and metallographic techniques. By electron microscopy they obtained some evidence that the Fe_3C went into solution and the Cr_7C_3 was separately nucleated. Crafts and Lamont[4] have extracted the carbides from tempered chromium steels and examined them in the electron microscope. In their view, the iron carbide passes to the chromium carbide through a transitional structure. Kuo[5] also extracted the carbides from a steel containing 0·35% C, 12·2% Cr, analysed them and examined them by

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Table I

ANALYSES OF STEELS, wt-%

	C	Cr	V	Si	Mn	S	P
H	0·21	9·09	...	0·38	0·36	0·036	0·021
A	0·22	9·03	0·38	0·34	0·18	0·032	0·020
D	0·22	8·99	0·97	0·18	0·27	0·022	0·018
F	0·23	...	0·97	0·20	0·33	0·042	0·017

X-rays. He put forward an alternative mechanism by which the Cr_7C_3 is formed in the existing Fe_3C particles. Electron micrographs of carbide extracts by Wever and Koch[6] give clear evidence that such transformations can occur *in situ*. Nevertheless, there is evidence to associate the onset of secondary hardening in alloy steels with the precipitation of finely dispersed carbides. One difficulty has been that the new phase could only be detected by X-ray examination of carbide extracts after the peak hardness had been passed. However, recently Kuo[7] has obtained a better correlation by examining carbide extracts from molybdenum steels directly in the electron microscope.

Recent work by Shaw and Quarrell[8] on the carbides in low-carbon, chromium–vanadium steels has defined clearly the equilibrium carbides over a wide range of composition at 700° C. For the present work certain of these steels were chosen for investigation of the approach to equilibrium, particularly at lower temperatures. It was of interest to choose a high-chromium steel (~9%) because it was then possible to study not only the successive formation of Fe_3C and Cr_7C_3, but also the formation of $Cr_{23}C_6$. Fortunately, at the beginning of this work, much-improved electron microscopic techniques became available; consequently it was possible to give close attention to the question of nucleation of the two chromium carbides.

EXPERIMENTAL METHODS

The general approach to the problem was to examine in several ways small tempered specimens on which hardness measurements had been carried out. The optical and electron microstructures were studied, and identification of the several carbides was established by X-ray analyses of carbide extracts, and electron diffraction studies of extraction replicas.

Materials and Heat-treatments

The steels were prepared in a small, high-frequency furnace and cast into 7½-lb tapered ingots about 2-in. square which were forged down to 1-in. dia. rods. The analyses are shown in Table I.

The specimens were homogenized in argon for 4 h at 1200° C, followed by oil quenching to give a fully martensitic structure in the case of steels H, A, and D. Steel F was brine-quenched to give a bainitic structure. Tempering treatments up to 1000 h were carried out in salt baths, at temperatures controlled to ± 3° C.

Extraction of Carbides

Carbides were extracted from the tempered steels by the method of Crafts and Lamont,[9] i.e. electrolysis in 5% hydrochloric acid with a current density of 0·025 A/cm² using a glycerine layer at the bottom of the cell.

X-ray diffraction powder photographs were taken on a 9-cm camera in the usual way. In the later stages of the work, the method was largely replaced by electron diffraction photographs taken through extraction replicas.

Electron Microscopy

The tempered specimens were electropolished in a bath containing 950 ml acetic acid, 50 ml 1·56 sp.gr. perchloric acid, the voltage across the cell being 50–60V. After a preliminary examination in the optical microscope to check the degree of etching, replicas were prepared for examination in a Vickers E.M.3 electron microscope. Two main types of replica were used:

(i) Carbon replica
(ii) Carbon extraction replica.

The former were prepared in two ways. First, a method due to Bradley[10] was used in which an ordinary Formvar replica of the metal surface is initially prepared. This is then placed in a high vacuum, and carbon evaporated on to it from an arc. A deposit of about 50 Å thick is applied, sufficient to give a slight brown tinge to a white porcelain indicator. Finally, the plastic film is dissolved away in dioxan. Alternatively, the intermediate Formvar film can be dispensed with in the way described by Smith and Nutting,[11] who evaporated the carbon film directly on to the metal specimen. The film is then released by electropolishing. As carbon films enable a resolution better than 50 Å to be attained, the microscope became the limiting factor in the achievement of high resolution.

Extraction replicas were first made by Fisher,[12] who applied a plastic film to steel specimens which were then etched through the film to release small particles (e.g. carbides) which clung to the film when it was removed. Nutting and Smith[11] have now improved this method by use of a carbon film which

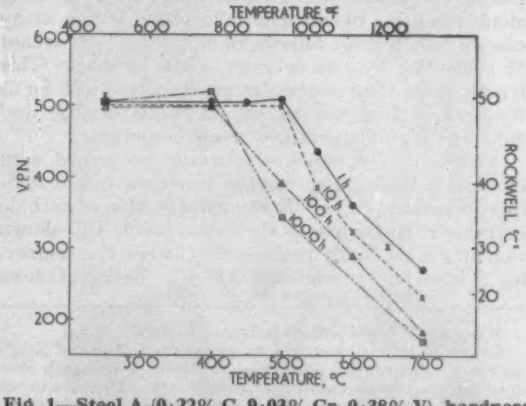


Fig. 1—Steel A (0·22% C, 9·03% Cr, 0·38% V), hardness curves for different tempering times

Fig. 2—Steel A, as oil-quenched, carbon replica shadowed with Au–Pd × 15,000

Fig. 4—Steel A, tempered 1000 h at 400° C, carbon replica shadowed with Au–Pd × 15,000

Fig. 3—Steel A, tempered 1 h at 250° C, carbon replica shadowed with Au–Pd × 15,000

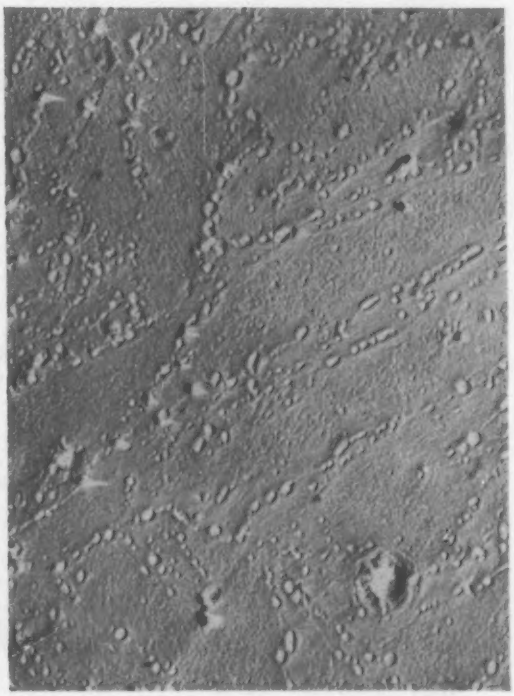
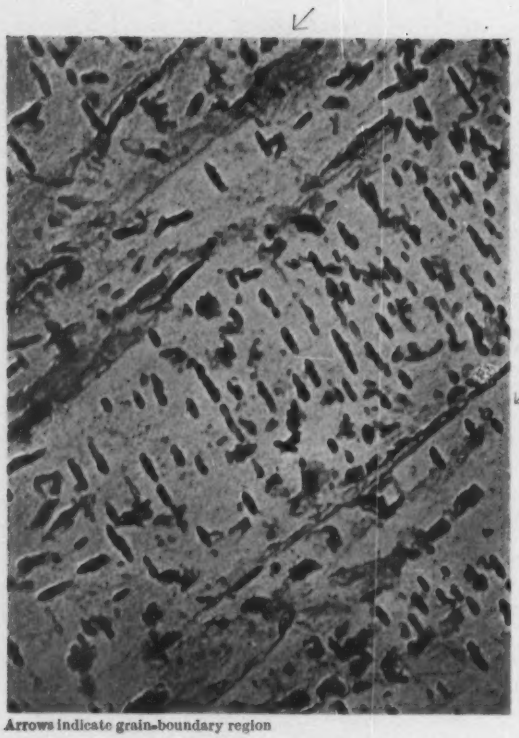
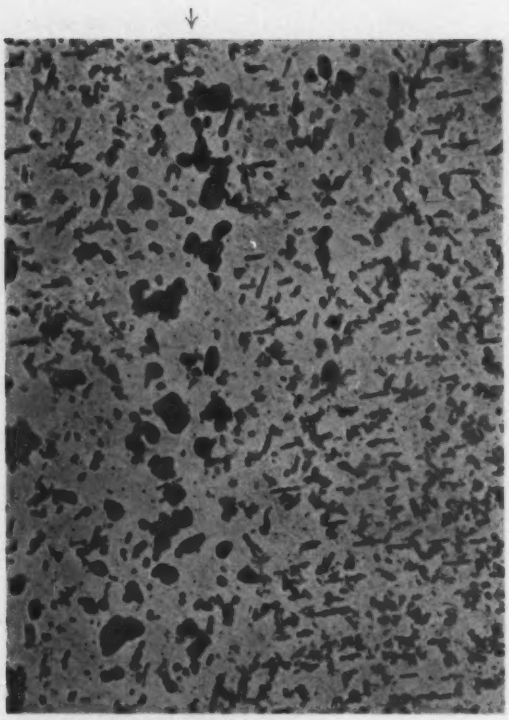


Fig. 5—Steel A, tempered 1 h at 700° C, carbon replica shadowed with Au–Pd × 15,000



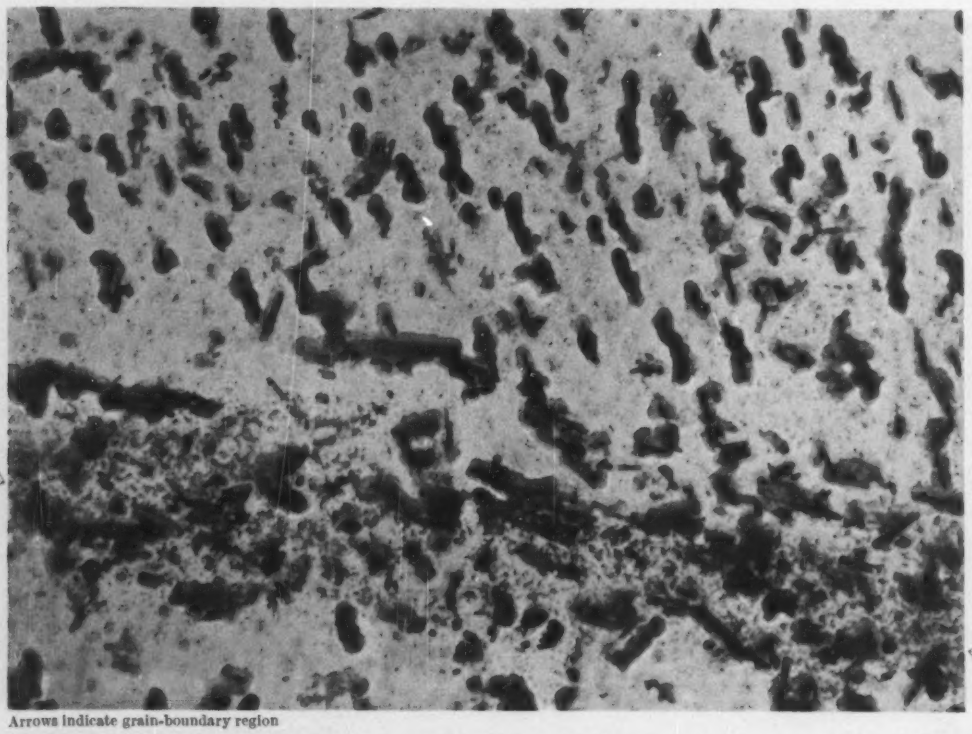
Arrows indicate grain-boundary region

Fig. 6—Steel A, tempered 1 h at 500° C, carbon extraction replica × 28,000



Arrow indicates grain-boundary region

Fig. 7—Steel A, tempered 1000 h at 500° C, carbon extraction replica × 28,000



Arrows indicate grain-boundary region

Fig. 8—Steel H, tempered 10 h at 500° C, carbon extraction replica × 28,000

Fig. 9—Steel D, tempered 1 h at 550° C, carbon extraction replica × 28,000

Fig. 10—Steel F, tempered 100 h at 500° C, carbon extraction replica × 250,000

provides a much better support for the particles and yields more satisfactory results.

The carbides occupy the place in the replica corresponding to that which they occupied in the metal. As electron diffraction photographs of extremely small regions can be readily made in most modern electron microscopes, the use of extraction replicas permits the positive identification of a precipitate in the early stages of development, when X-ray diffraction of carbide extracts gives a negative or insufficiently precise result.

EXPERIMENTAL RESULTS

Formation of Fe_3C, Cr_7C_3, and $Cr_{23}C_6$ during Tempering

Steel A (9·03%Cr, 0·38%V) was chosen for detailed investigation of the mode of formation of the carbides, because previous work by Shaw and Quarrell[8] had shown that at 700° C, Cr_7C_3 was first formed followed by transformation to $Cr_{23}C_6$. In the present investigation, specimens were tempered in the range 250–700° C for periods from 1 to 1000 h. The results of hardness tests over this range of temperature for a series of different tempering times are shown in Fig. 1. With the shorter tempering times of 1 h and 10 h, after an initial drop from the as-quenched hardness of 570 V.P.N., a hardness of 500 V.P.N. is maintained between 250° and 500° C; above this temperature it falls rapidly. A rise due to secondary hardening as distinct from maintenance of hardness, only occurred in the curve for 1000-h treatments, but in this case the hardness fell rapidly above 400° C.

The microstructure of the as-quenched steel as revealed in the electron microscope was fully martensitic (Fig. 2); as a result of differential etching some needles were revealed more readily than others.

Tempering at 250° C—Specimens tempered for 1 h at 250° C already showed a pronounced change in the microstructure corresponding to the initial drop in hardness. A fine Widmanstätten precipitation was visible within the martensite needles (Fig. 3), the rods being about 1200 Å long and 200 Å wide, but there was no marked preferential precipitation at the boundaries of the martensite needles. X-ray examination of the extracted carbides at this stage yielded faint diffuse lines which corresponded to the structure of Fe_3C. The evidence, however, suggested that either the structure was not perfect or that the particle size was very small. The structure already evident after 1 h was unchanged after tempering for 1000 h, as was the hardness of the specimen.

Tempering at 400° C—After 1 h at 400° C, the electron microstructure was very similar indeed to that occurring after the tempering treatments at 250° C. As the carbide particles were not appreciably coarser, it seemed clear that the alloying elements had markedly inhibited their growth. This is reflected in the hardness curve where the hardness resulting from 1-h treatments is practically unchanged over the range 250–450° C. Prolongation of the tempering at 400° C resulted in a marked change in the microstructure. After 1000 h it was clear that the rodlets of Fe_3C were dissolving in the matrix (Fig. 4). In Fig. 4 fewer are visible than in Fig. 3; furthermore, in Fig. 4 many of the rodlets are thinned at the ends and appear irregular, indicating clearly that they are dissolving in the matrix. In the same photograph fine spheroidal particles of a new precipitate are visible, the smaller ones being of the order of 80 Å or less in diameter. This precipitate showed some preference for the boundaries of the martensite needles with the result that precipitation was more advanced in these regions. The occurrence of this precipitate corresponded with a rise in hardness of only 20 V.P.N. (Fig. 1).

Tempering at 500° C—Specimens tempered at 500° C for 1 h showed a slight increase in hardness (Fig. 1), and electron microscopic examination showed clearly the presence of two types of precipitate, the rods of Fe_3C and a new spheroidal precipitate. X-ray diffraction photographs taken on the carbide extract at this stage again indicated only Fe_3C. X-ray diffraction photographs taken after 10 h were blank, probably because the precipitates were present in such a finely divided form that recognizable diffraction rings were not obtained. After 100 h at 500° C, Cr_7C_3 was first detected in X-ray diffraction photographs from the carbide extract. At this stage the hardness had already dropped markedly, and the electron micrographs showed that much Fe_3C had gone into solution and that the new precipitate Cr_7C_3 had coarsened substantially particularly at the acicular grain boundaries. The hardness at this stage was less than 350 V.P.N., the drop resulting from the rapid coarsening of the Cr_7C_3 precipitate.

Tempering at 700° C—After only 1 h tempering at 700° C, Cr_7C_3 was the sole precipitate. Figure 5 shows that the finer precipitate in the interior of the grains has dissolved and coarser particles are growing in the vicinity of the old martensite needle interfaces, now the acicular ferrite boundaries. X-ray diffraction photographs of carbide extracts showed that the transformation of Cr_7C_3 to $Cr_{23}C_6$ had started between 10 and 100 h. Specimens in this range were carefully examined and no separate nucleation of the $Cr_{23}C_6$ was detected. It would appear that the transformation occurs *in situ* in the existing Cr_7C_3 by diffusion inwards of chromium.

Further Results on the Transformation from Fe_3C to Cr_7C_3

The carbon replicas referred to in the previous section have enabled the detection of a second precipitate at a much earlier stage than X-ray diffraction photographs of the carbide extracts revealed the presence of Cr_7C_3. However, use of an extraction replica technique enables closer study to be made of the transformation from Fe_3C. The photographs obtained show a somewhat greater density of carbides than would be expected in an ordinary electron micrograph for a carbon content of 0·2%. However, this disadvantage is outweighed by the fact that the actual particles in a given region can be identified by electron diffraction. Specimens of steel A tempered at 500°C for different times were examined in this way. After tempering for 1 h the carbides were primarily rodlets of Fe_3C, some of which were very thin, presumably because they were going into solution. However, at the acicular interfaces a fine, cloud-like precipitate was already visible in the original photo-

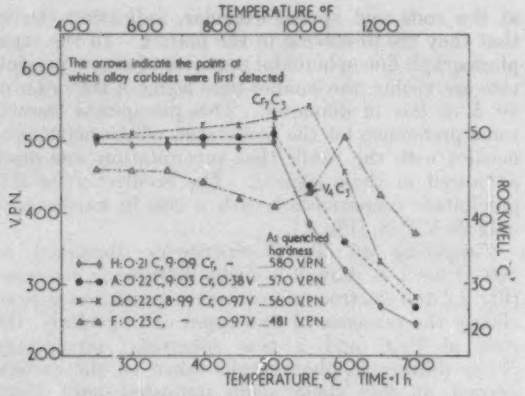

TEMPERATURE, °F
400 600 800 1000 1200
The arrows indicate the points at which alloy carbides were first detected
Cr_7C_3
M_4C_3
As quenched hardness
H: 0·21 C, 9·09 Cr, – ... 580 V.P.N.
A: 0·22 C, 9·03 Cr, 0·38 V ... 570 V.P.N.
D: 0·22 C, 8·99 Cr, 0·97 V ... 560 V.P.N.
F: 0·23 C, – 0·97 V ... 481 V.P.N.
VPN
ROCKWELL 'C'
TEMPERATURE, °C TIME-1 h

Fig. 11—Hardness curves for steels H, A, D, and F for 1 h tempering time

graphs, the first sign of precipitation of Cr_7C_3 (Fig. 6). The particle size of this precipitate was beyond the resolution of the microscope and thus smaller than 50Å. At this stage electron diffraction photographs taken through the replica revealed only Fe_3C. This structure resulted in the maximum hardness obtained by 1-h tempering treatments (510 V.P.N.).

After 10 h the Fe_3C rodlets were noticeably more transparent to the electron beam, and a very fine precipitate was visible in many regions, particularly near grain boundaries. At this stage X-ray photographs revealed nothing, and electron diffraction photographs from the replica still showed only Fe_3C. However, after 100 h at 500° C when a new precipitate was clearly visible, Cr_7C_3 was detected both by X-ray diffraction and electron diffraction. The precipitation was much further advanced at the ferritic grain boundaries; this became particularly evident after tempering for 1000 h at 500° C. Figure 7 shows the distribution of tabular Cr_7C_3 particles concentrated near the grain boundaries, while within the grains can be seen small Cr_7C_3 particles which are greyish in colour for they are thin enough to transmit some of the electron beam; some rodlets which may be residual Fe_3C are also visible. The latter could not be detected by X-ray or electron diffraction.

It is clear from the photographs of the extraction replicas that much of the Cr_7C_3 is formed by separate nucleation; nucleation within the particles of Fe_3C cannot be excluded, but in this case it is considered that the separately nucleated particles are responsible for the changes in hardness.

Role of Vanadium during Tempering of 9% Chromium Steels

Of the steels investigated, three provide relevant information on the influence of vanadium on the tempering of a 9% chromium steel. Steel H containing 0·2% carbon, 9% chromium, and no vanadium can be compared with steels A and D which contained in addition 0·38% and 0·97% vanadium respectively. The earlier work of Shaw and Quarrell has indicated that in all these steels, vanadium carbide would be absent and that the carbide reactions would be $Fe_3C \rightarrow Cr_7C_3 \rightarrow Cr_{23}C_6$, so the effect of vanadium on these transformations could be directly studied.

The hardness temperature curves for the three steels over the range 250–700° C are shown in Fig. 11 for a tempering time of 1 h. In the absence of vanadium, the chromium steels show no secondary hardening peak; however, the hardness is maintained at about 500 VPN over the range 250–500° C, while Fe_3C is the precipitating carbide. The tempering curves for different times shown in Fig. 12 confirm that over a wide range of tempering times and temperatures, the straight chromium steel shows no secondary hardening peak, but the characteristic maintenance of hardness occurs at 400° C even after 1000 h tempering.

The curve for steel A in Fig. 11 shows that 0·38% vanadium already has an appreciable effect on the tempering behaviour and this is further confirmed by comparison of the results for different tempering times in Figs. 1 and 12. However, when the vanadium content is increased to 0·97% the difference from the straight chromium steel is quite pronounced. The hardness starts to rise in the range 300–500° C and a secondary hardening peak developed in this steel after tempering for 1 h at 550° C (Fig. 11), the hardness difference between this and a plain chromium steel after the same treatment amounting to over 150 VPN. A marked difference in hardness was maintained after tempering at 600° C, but became much less pronounced at high temperatures. Tempering for longer times (Fig. 13) did not lead to a pronounced secondary hardening peak.

Electron micrographic examination of the vanadium-free steel H after tempering at 500° C revealed clearly the presence of two precipitates. Figure 8 shows a typical extraction replica from a specimen tempered 10 h at 500° C, after which treatment the hardness has begun to drop. In the acicular grain boundary region the Cr_7C_3 precipitate can be resolved as very fine particles (< 100 Å) although this precipitation is less advanced in the interior of the grains. The cementite rodlets show signs of re-solution and have developed ' haloes ' or external layers of material more transparent to electrons. This may be a result of the dissolution process, but could also be interpreted as evidence for the transformation of Fe_3C to Cr_7C_3 *in situ*.

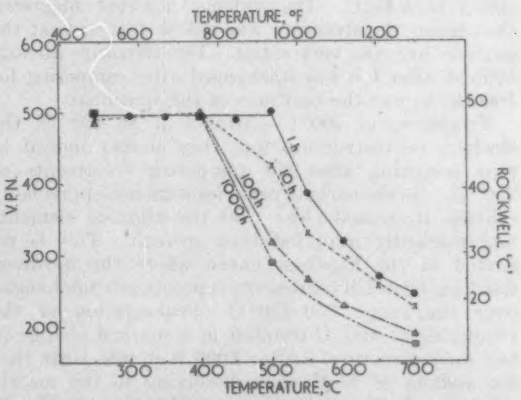


Fig. 12—Steel H (0·21% C, 9·09% Cr), hardness curves for different tempering times

Electron micrographic examination of steel D (0·97% V) after the optimum tempering treatment of 1 h at 550° C, also revealed the presence of two precipitates. There were residual rods of cementite and a very fine precipitate which could barely be resolved, the particles being less than 100 Å in diameter (Fig. 9). X-ray analysis of the carbide extract showed only the presence of cementite but electron diffraction of an extraction replica indicated the presence of a Cr_7C_3 type carbide, confirming the electron micrographic observations.

The behaviour of the fine Cr_7C_3-type precipitation was studied in the three steels, H, A, and D, over a range of tempering temperatures. It was found that not only did the Cr_7C_3 precipitate form earlier in the high-vanadium steel D, but it also remained finer at higher temperatures than in steels A and H (c.f. Figs. 6, 8, and 9). It should be pointed out that X-ray examination of the carbide extracts revealed the Cr_7C_3 precipitate later in steel D than in steels A or H. This is merely a reflection on the limitations of the X-ray method when attempting to detect and identify any finely divided phases.

Behaviour of a Vanadium Steel

To complete the survey it was decided to study a steel containing 1% vanadium but no chromium (steel F). In this steel cementite first precipitates but is replaced by V_4C_3 at higher temperatures. Thus a comparison of the influence of the two carbides on secondary hardening could be made.

The tempering curve over the range 250–700° C is included in Fig. 11. It is very different from the curves for the three chromium steels. The curve falls continuously from 250° to 500° C over which range only Fe_3C was present after treatments of 1 h. Electron microscopic examination showed that the softening coincided with an increase in the size of the cementite particles; some very coarse particles of Fe_3C even persisted as high as 600° C. After 1 h at 550° C much of the cementite had redissolved, and was replaced by a very nebulous precipitate which could not be resolved in the electron microscope used. Electron diffraction photographs taken from extraction replicas confirmed that a fine dispersion of V_4C_3 had been formed. This coincided with the

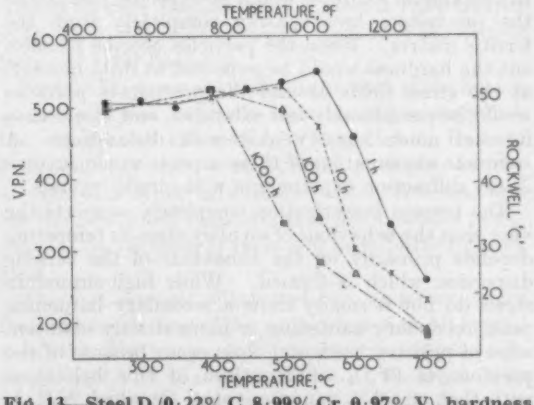


Fig. 13—Steel D (0·22% C, 8·99% Cr, 0·97% V), hardness curves for different tempering times

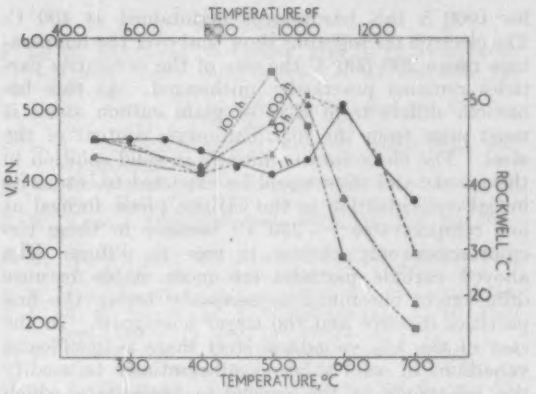


Fig. 14—Steel F (0·23% C, 0·97% V), hardness curves for different tempering times

sharp rise in hardness which occurred in the range 550–600° C for tempering times of 1 h. Consequently, further examination of the replicas was made on a new Siemens electron microscope capable of a resolution approaching 10 Å. Rodlets of vanadium carbide about 20 Å wide and 50–100 Å long were detected after tempering 100 h at 550° C (Fig. 10). The particles became spheroidal (100–200 Å dia.) when the hardness peak was passed.

The behaviour of the steel after different tempering times is given in Fig. 14 which shows the extent of the displacement of the marked secondary hardening peak to lower temperatures for the longer times. After 1000 h the peak occurs at 500° C and the inference from the curves is that V_4C_3 is formed at temperatures as low as 450° C. The maximum hardness (600 V.P.N.) was obtained after 475 h at 500° C when an increase of about 200 points on the V.P.N. scale was obtained. At this stage there is general precipitation of spheroidal V_4C_3 about 100 Å in diameter or less, together with some coarse particles of Fe_3C which are gradually going into solution.

DISCUSSION

While the phenomenon of secondary hardening has long been considered a normal precipitation hardening process, it is only very recently that direct metallographic evidence in support of this view has been obtained. The X-ray examination of carbide extracts has been rather misleading in so far as the alloy carbides can only be detected in this way when they have grown substantially in size, and when the peak hardness has been passed. Kuo[7] has demonstrated recently that an extraction replica technique permits the detection of Mo_2C in a steel containing 0·11%C and 2·14%Mo just before the peak hardness is obtained. Likewise, in the present work the presence of Cr_7C_3 in a 9% chromium steel has been detected at temperatures as low as 400° C, while V_4C_3 has been detected by electron diffraction in extraction replicas when a 1%V, 0·23%C steel is tempered at 500° C prior to the secondary hardening peak.

An important feature of the steel based on 9% chromium is the maintenance of a hardness of about 500 V.P.N. from 200° up to 500° C; even on tempering

for 1000 h this hardness is maintained at 400° C. The electron micrographs show that over the temperature range 200–500° C the size of the cementite particles remains practically unchanged. As this behaviour differs from that of plain carbon steels it must arise from the high chromium content of the steel. The chromium is initially in solid solution in the matrix and thus would be expected to retain its initial concentration in the carbide phase formed at low temperatures (~ 250° C) because in these circumstances only carbon is free to diffuse. The alloyed carbide particles are more stable because diffusion of chromium is necessary before the fine particles dissolve and the larger ones grow. In the case of the 1% vanadium steel there is insufficient vanadium in solid solution substantially to modify the behaviour of the cementite precipitate which coarsens in the range 250–500° C with a consequent fall in hardness.

The above observations suggest that the addition of 0·38–1% vanadium to the 9% chromium steel does not markedly alter the behaviour of the cementite in the range 250–500° C. However, these vanadium additions influence the tempering curves in the temperature range 400–550° C. The electron microscopic observations have shown that in this range Cr_7C_3 is precipitating and it is thus this reaction in which the vanadium is significant to the extent of forming a secondary hardening peak which is absent in the straight chromium steel. The vanadium causes the Cr_7C_3 precipitate to remain finely dispersed and to cause positive hardening, whereas in the absence of vanadium, the hardening effect of the Cr_7C_3 is only sufficient to overcome the softening due to the solution of cementite. The present work on the straight Cr steel confirms that of Heiskaner[13] who showed that in a 12%Cr steel, Cr_7C_3 present after 1 h at 525° C subsequently grows rapidly.

That vanadium can exist in a high concentration in Cr_7C_3 is shown by Shaw and Quarrell[8] who found that with steel A (9%Cr, 0·38%V) after tempering 1 h at 700° C, the metal–atom ratios in Cr_7C_3 were:

Fe	Cr	V
0·23	0·36	0·41

The high vanadium content of the carbide thus stabilizes it in a finely divided form, presumably because the vanadium restricts the diffusion of chromium into the ferrite, a process which must take place if coarsening of the carbide occurs.

The results obtained with extraction replicas in the present investigation show that in the steels studied the transformation $Fe_3C \rightarrow Cr_7C_3$ occurs by re-solution of the cementite and a nucleation of Cr_7C_3 occurring in the first stages in the vicinity of the acicular boundaries. This reaction must involve the diffusion of both chromium and carbon atoms and the present experiments indicate that this is possible at temperatures as low as 400° C. The possibility of the transformation of Fe_3C *in situ* is not excluded (*see* e.g. Fig. 8) but it is difficult to see how this reaction could bring about the secondary hardening which occurred in steels A and D. Furthermore, the habit of the two carbides is sufficiently distinct to allow clear interpretation of the electron micrographs. Particles of Cr_7C_3 were first detected when they were less than 100 Å dia.: these small spheroidal particles clearly did not form *in situ* in the Fe_3C rodlets although some of the larger particles observed later may well have done.

The precipitation of Fe_3C occurs primarily within the martensitic needles and not at their boundaries, whereas the precipitation of Cr_7C_3 begins at the boundaries. This suggests that the boundary region differs from the rest of the steel. Tsou, Nutting, and Menter[15] have shown that in quenched Armco iron, austenite is often retained as a thin layer in grain boundary regions. Very recently, Hsaio[14] has shown that slowly cooled, low-carbon steels also retain a thin film of austenite at the grain boundaries at room temperature. If this is so in the present steels, it could explain the absence of Fe_3C precipitation in grain boundaries in the range 250–400° C because of the higher solubility of carbon in austenite. Recent electron micrographs by the present authors, of quenched steels tempered at low temperatures (< 400° C), indicate that thin films do occur at the martensite interfaces. It would thus follow that at temperatures of 400° C and higher the retained austenite will have transformed and the cloud-like precipitate of Cr_7C_3 which begins to form at the boundaries may do so because of the higher carbon concentration there. General precipitation of Cr_7C_3 within the grains subsequently takes place during the re-solution of cementite which provides the carbon. At a later stage still, the Cr_7C_3 precipitate coarsens by solution of the finer particles and selective growth. This growth occurs primarily at the acicular grain boundaries where it can be predicted on thermodynamic grounds that a segregation of chromium (and vanadium) atoms should occur. The present metallographic evidence suggests that the $Cr_7C_3 \rightarrow Cr_{23}C_6$ transformation occurs substantially *in situ* and not by separate nucleation and growth.

The hardness of the four steels investigated drops very rapidly once the critical temperature or time is exceeded. The sudden change in behaviour is hard to explain simply on the basis of a coarsening carbide dispersion. The concept of lattice coherency between the carbide and matrix offers a more satisfactory explanation of the phenomena, for in these terms the maximum hardness would be expected just before the precipitate breaks away completely from the ferritic matrix. When the particles become incoherent the hardness would be expected to drop quickly, as the stress fields around the precipitate particles would be considerably less extensive, and would thus interact much more weakly with dislocations. A complete examination of these aspects would involve X-ray diffraction experiments with single crystals.

The present investigation completely supports the view that the behaviour of an alloy steel on tempering depends primarily on the behaviour of the carbide dispersion which is formed. While high-chromium steels do not normally show a secondary hardening peak, secondary hardening or more strictly maintenance of primary hardening does occur because of the presence of Cr_7C_3. Comparison of this behaviour with that of a 1% vanadium steel (in which V_4C_3 is the effective precipitate) leads to the conclusion that

the various alloy carbides differ in their effects partly because of differences in their tendency to remain as a fine dispersion. For example, the behaviour of a 9% chromium steel is substantially altered by the addition of 1% vanadium to the steel; this does not change the carbide type but influences the rate of coalescence of the carbide. This seems to be a matter of alteration of relative diffusion rates of the atoms of the alloying elements, but it is probable that in a full analysis of the problem, the question of coherency of the carbides with the ferritic matrix will have to be considered. It is in this connection that differences in the crystal structure of the alloy carbides will be significant.

Acknowledgments

We would like to thank our colleagues, in particular Professor A. G. Quarrell and Mr. R. Smith, for their interest and helpful discussions.

Our thanks are also due to Dr. T. P. Hughes and Dr. J. Menter for use of the Siemens electron microscope at the Tube Investments Research Laboratory, Hinxton Hall, Cambridgeshire.

One of us (A.K.S.) gratefully acknowledges financial support from the Government of West Bengal.

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Sussex Ecclesiastical Ironwork—I

Until the Industrial Revolution, Sussex was one of the major centres of the British iron and steel industry. The products of the Sussex furnaces and forges became famous all over England; this subject is fully treated in Dr. H. R. Schubert's recent " History of the British Iron and Steel Industry."

Some of the finest examples of the work of the Sussex ironmasters was, naturally enough, used to embellish the churches of the county. Miss Helena Hall, of Lindfield, has drawn many fine examples of the wrought-iron work in various Sussex churches, and she has generously made her sketches available to the *Journal*. A selection of these will be published during 1958.

The first example, illustrated here, is a footscraper from the south door of the parish church of All Saints, Lindfield. The scraper is 17½ in. high and 16¼ in. wide at the base. It was made in 1866 by Phinehas Jupp of Lindfield. The church itself is largely 14th century with some 15th century additions.

The Properties of Some Silicon–Molybdenum Steels

By A. S. Kenneford, M.Sc., F.I.M., A.M.I.Mech.E.

SYNOPSIS

The paper deals with the heat-treatment and mechanical properties of a series of steels having silicon and molybdenum as the only alloying elements. These steels, owing to their small volume changes on transformation, are resistant to thermal stress-cracking, and also show great resistance to softening after tempering at temperatures up to about 550° C. They also exhibit good ductility and impact value after tempering to give tensile strengths in the neighbourhood of 120 tons/in². 1420

Introduction

AS A RESULT OF WORK previously carried out on the effects of alloying elements on the volume change at Ac_3 in steel,[1] and also on their effect on martensite breakdown in quenched steel during tempering,[2] it was concluded that steels containing silicon up to about 2% and molybdenum up to about 0·75% might possess useful properties. The reasons for this conclusion were:

(*a*) Both silicon and molybdenum reduce the volume change at Ac_3 on heating
(*b*) Both silicon and molybdenum confer hardenability without greatly lowering the M_s temperature
(*c*) Both elements delay softening on tempering: silicon by raising the temperature at which martensite finally decomposes into ferrite and cementite, and molybdenum by secondary hardening due to the formation of complex carbides.

COMPOSITION OF MATERIAL USED

Four small casts of silicon–molybdenum steel containing about 2% Si and 0·75% Mo, with carbon contents varying from 0·3% to 0·6%, were obtained from the trade. The compositions are shown in Table I.

DILATOMETRIC ANALYSIS

The critical ranges of the four steels and the temperatures of the various stages of martensite breakdown were determined using a Leitz Universal dilatometer. The heating and cooling rates were automatically controlled and were respectively 5° C and 2·5° C/min with corresponding maximum temperatures of 1000° and 550° C for the two sets of determinations. Table II shows the results obtained.

Because of the high silicon content the Ac_3 temperatures of all the experimental steels were high, and this necessitated the use of a high quenching temperature for satisfactory hardening. As was expected from previous work, the volume changes which occurred at the $\alpha \rightarrow \gamma$ phase change were all much lower than those normally found in conventional alloy steels. Figure 1 shows a typical dilatometer record for the 0·6% carbon steel.

Table II also shows the high tempering temperatures required to complete the breakdown of the martensite into ferrite and cementite. A dilatometer diagram for the tempering of the 0·56% carbon steel is given in Fig. 2. For comparison a similar diagram made under identical conditions of heating and cooling, for a Ni–Cr–Mo steel containing 0·55% carbon, is shown in Fig. 3. These two diagrams illustrate clearly the delaying effect of silicon on the final decomposition of martensite, and hence on the final softening brought about by tempering.[3]

The two stages of martensite breakdown were easily visible on the hardness/tempering curves for each of the four steels. Another interesting feature was their almost complete lack of softening as the tempering temperature was raised from 220° to 350° C, i.e. between the end of the first stage and the beginning of the third stage of martensite breakdown (Fig. 4). The hardness of each of the steels after being tempered for 60 min at 700° C was in the neighbourhood of 300 D.P.N.

Table I

COMPOSITION OF Si–Mo STEELS

%						
C	Si	Mn	S	P	Cr	Mo
0·31	1·97	0·30	0·040	0·026	0·54	0·84
0·41	2·12	0·29	0·045	0·026	0·29	0·75
0·56	2·11	0·68	0·047	0·032	0·24	0·73
0·61	2·23	0·28	0·035	0·023	0·22	0·78

Residual nickel was below 0·1% in each of the four steels.

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Mr. Kenneford is at the Ministry of Supply, Armament Research and Development Establishment, at Woolwich.

Table II
RESULTS OF DILATOMETRIC ANALYSIS

Carbon, %	Temp., °C		Volume Change at Ac_3, %	Quenching Temp., °C	Stage I °C	Stage III °C	Contraction of Volume, %
	Ac_1	Ac_3					
0·31	794	836–924	0·012	970	75–220	353–502	0·205
0·41	793	822–899	Nil	950	72–220	349–500	0·379
0·56	788	812–875	0·036	920	74–220	358–516	0·693
0·61	792	812–843	0·037	900	73–228	359–506	0·575

END QUENCH HARDENABILITY

End-quench hardenability tests were made on standard specimens quenched under standard conditions from soaking temperatures 50° C above the Ac_3 temperatures determined dilatometrically. The results are given in Fig. 5, which shows clearly the effect of the high manganese content of the 0·56% carbon steel.

MECHANICAL PROPERTIES

The ambient temperature mechanical properties of the steels were determined after tempering at temperatures from 20° C (as quenched) to 700° C. The blanks, from which the tensile test-pieces were made, were water-hardened from the appropriate temperature, tempered for 60 min, and finally wet-ground and lapped to size (0·357-in. dia. gauge length). Table III records the average results of duplicate tests.

The reason for the low ductility values given by the 0·56% carbon steel is not known, and insufficient material was available for further tests.

The results confirm previous findings by the author and other workers[4] on the low limit of proportionality and yield point of martensite, and show that, by low-temperature tempering, the yield point and ductility can be raised considerably with but little lowering of the maximum stress. Tempering, at a temperature corresponding approximately to that of the end of the first stage of martensite breakdown, produced the optimum combination of strength and ductility, and, in the case of the 0·31% carbon steel, it was possible to obtain the following combination of properties by tempering at 220° C:

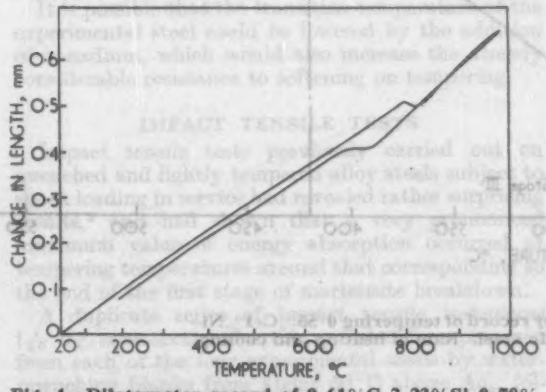

Fig. 1—Dilatometer record of 0·61%C–2·23%Si–0·78% Mo steel. Rate of heating and cooling, 5° C/min. Volume change at Ac_3, 0·037%

D.P.N. 30 kg	0·2% Proof Stress, tons/in²	Max. Stress, ton/in²	Red. in Area, %	Charpy Impact (V-notch), ft-lb
578	97·5	119·7	44	16·4

The steels also showed little variation in mechanical properties when tempered over the range 220–350° C. The lowering of ductility, brought about by tempering the 0·31% carbon steel at temperatures between 75° and 150° C, is interesting, and may be caused by the progressive precipitation of the carbide $Fe_{2\cdot4}C$ from the martensitic matrix at temperatures which are not high enough to bring about any appreciable reduction in the internal stress in the material. Higher tempering temperatures, e.g. 220° C, whilst resulting in complete precipitation of the carbide $Fe_{2\cdot4}C$, which in the steel under discussion cannot be present in large amounts, also cause a loss of tetragonality of the remaining martensite, accompanied by a considerable reduction in internal stress, and a concomitant increase in elastic limit and ductility.

The results, in general, indicate that the steels have high yield points (0·2% proof stress) and maximum stress, together with reasonable ductility after tempering at 600° C and that, even after tempering at 700° C, the yield points remain in the range 48–57 tons/in² with corresponding maximum stresses of 60–67 tons/in².

CHARPY IMPACT TESTS

Duplicate series of Charpy impact test pieces, 10 mm square section by 56 mm long, with a standard Izod notch placed centrally in one face, were prepared in the normal manner by water-quenching blanks from the appropriate temperature, tempering, and then wet-grinding to final dimensions. All notches were ground to shape by means of a profiled wheel, and were checked for accuracy of depth and contour before testing. Hardness tests were also made on each specimen as a check on the heat-treatment.

Trouble due to quench-cracking of the square-section blanks was practically absent and few rejects were obtained. This is in contrast to the large number of cracked specimens produced by water-quenching other alloy steels of similar carbon content.

Testing was done in a 30 m-kg Losenhausen machine. The summarized results are given in Table IV.

These results indicate that the steels are slightly susceptible to temper brittleness, particularly at the higher tempering temperatures. It has been noticed by other workers[5, 6] that the presence of molybdenum can cause temper embrittlement in some steels, and the values obtained with the steels under discussion are in agreement with this.

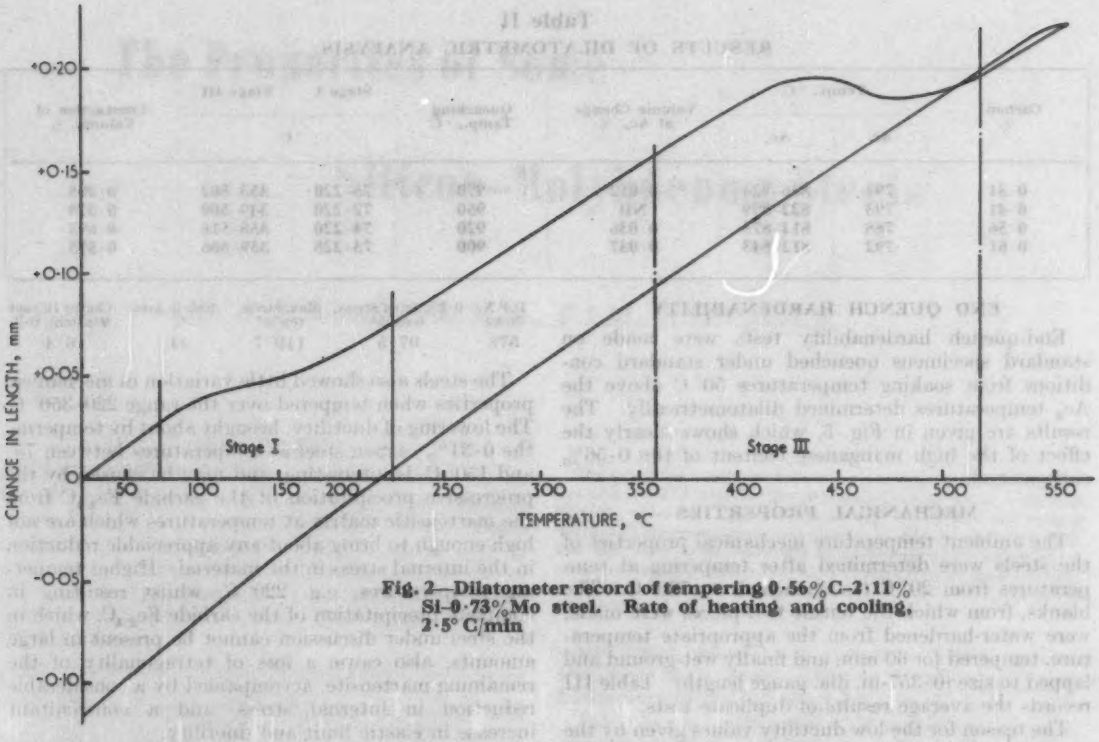

Fig. 2—Dilatometer record of tempering 0·56%C–2·11% Si–0·73%Mo steel. Rate of heating and cooling, 2·5° C/min

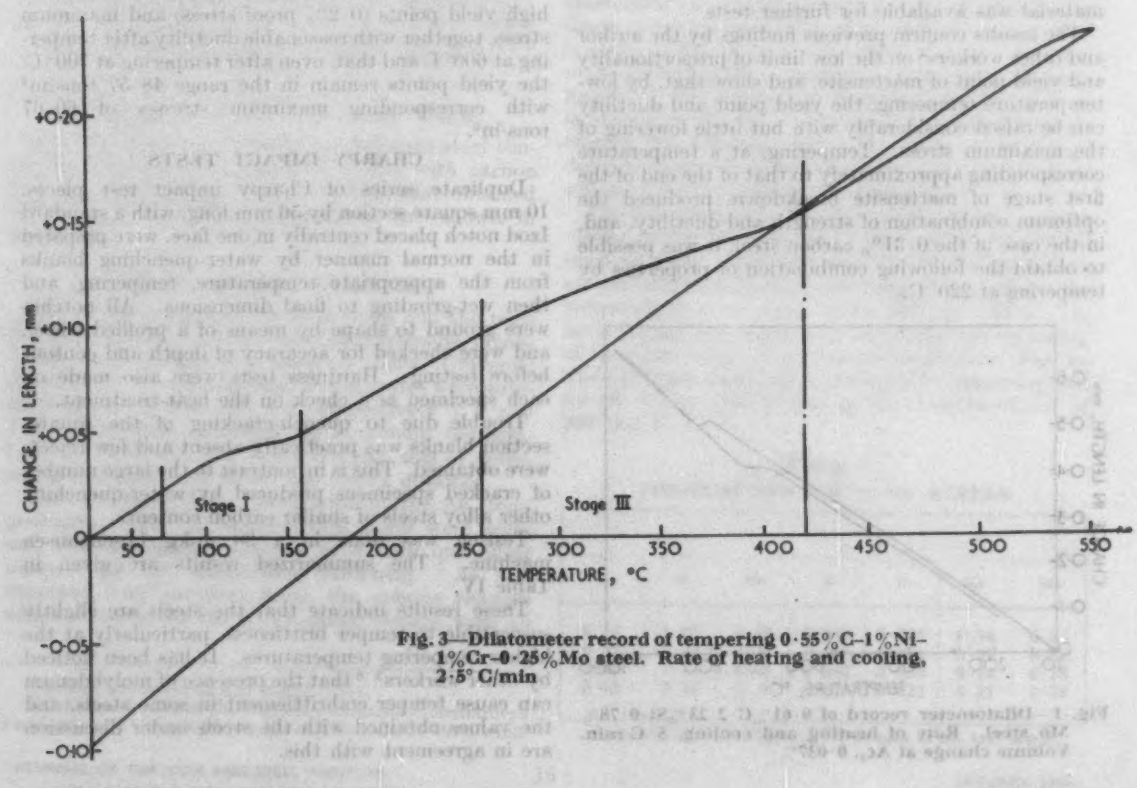

Fig. 3—Dilatometer record of tempering 0·55%C–1%Ni–1%Cr–0·25%Mo steel. Rate of heating and cooling, 2·5° C/min

The results given by the 0·31% carbon steel are remarkable in that the impact value varied little over the tempering range 20–500° C, the hardness having fallen meanwhile from 619 to 476 D.P.N. In the lower tempering temperature range, a maximum value of 18 ft-lb occurred at the end of the first stage of martensite breakdown (220° C) and thereafter the value fell slightly, reaching a minimum at about 450° C. This behaviour is contrary to that normally observed during the tempering of quenched steels, in which a minimum is generally found at tempering temperatures around the beginning of the third stage of martensite breakdown. This so-called ' third stage ' embrittlement is thought to be due to the formation of platelet cementite[7] in normal steels, and there is some evidence that, in high-silicon steels, the cementite is precipitated in a spheroidized form.[8]

The higher-carbon steels of the series had much lower impact values but behaved on tempering in much the same way as the material with a 0·31% carbon content.

IMPACT PROPERTIES AT SUB-ZERO TEMPERATURES

For comparative purposes, Charpy impact tests (**V**-notch) were carried out on a Ni–Cr–Mo steel to B.S.S. En.25 (0·31% C) and the 0·31% carbon Si–Mo steel. The specimens were water-quenched and then tempered to give hardness values in the range 300–340 D.P.N. All samples were water-quenched after tempering. The results obtained are summarized below and shown graphically in Fig. 6:

Type of Steel	Max. Energy, ft-lb	Mean Energy Transition Temp., °C	20 ft-lb Transition Temp., °C
En.25	59·3	−110	−140
Si–Mo	45·6	−10	−40

These results show that, for a comparable hardness in the quenched and tempered condition, the Si–Mo steel had a somewhat lower room-temperature impact value, together with a much higher transition temperature, than the standard En.25 steel of the same carbon content.

Preliminary tests at room temperature on the as-quenched or quenched and lightly tempered materials have shown, however, that the impact value of the Si–Mo steel is considerably superior to that of En.25.

It is possible that the transition temperature of the experimental steel could be lowered by the addition of vanadium, which would also increase the already considerable resistance to softening on tempering.

IMPACT TENSILE TESTS

Impact tensile tests previously carried out on quenched and lightly tempered alloy steels subject to shock loading in service had revealed rather surprising results,[9] and had shown that a very pronounced maximum value of energy absorption occurred at tempering temperatures around that corresponding to the end of the first stage of martensite breakdown.

A duplicate series of impact tensile test-pieces ($\frac{1}{40}$ in² cross-sectional area) was therefore prepared from each of the four experimental steels by water-quenching blanks from about 50° C above Ac_3, followed by appropriate tempering and wet-grinding to final size. The specimens were broken in an Izod

Table III

TENSILE TESTS ON WATER-QUENCHED AND TEMPERED Si–Mo STEELS (LONGITUDINAL)

C, %	Tempering Temp., °C	0·31							0·41							0·56							0·61						
		D.P.N. 30 kg	L. of P.	P.S.†	M.S.	Y.R.	E.	R.A.	D.P.N. 30 kg	L. of P.	P.S.†	M.S.	Y.R.	E.	R.A.	D.P.N. 30 kg	L. of P.	P.S.†	M.S.	Y.R.	E.	R.A.	D.P.N. 30 kg	L. of P.	P.S.†	M.S.	Y.R.	E.	R.A.
			tons/in²				%			tons/in²				%			tons/in²				%			tons/in²				%	
0·31	20	623	41	80·5	132	0·67	11	31	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
	75	616	43	93·5	*	...	2·4	6·6	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
	150	600	60	98	126·8	0·77	5·3	15	675	75·5	116·3	146·5	0·80	9·6	31	...	...	...	...	...	...	...	...	...	...	...	...	...	...
	220	578	61	97·5	119·7	0·83	14·4	44	643	88·8	113·8	124·7	0·85	10·4	34	...	...	...	...	...	...	...	...	...	...	...	...	...	...
	250	559	62	96·5	114·6	0·86	14	46	607	98	114·7	130	0·88	10	38	...	...	...	...	...	...	...	...	...	...	...	...	...	...
	300	488	65·5	84·7	97·2	0·87	19·5	50	517	85	96	106·1	0·88	12·3	39	...	...	...	...	...	...	...	...	...	...	...	...	...	...
	340	455	69	83·4	92·6	0·90	18	59	486	72	89·9	100·5	0·89	13·5	43	516	76	93	102	0·88	13·5	39·5	492	77	92·4	101·4	0·91	10·5	33
	400	390	57	65·8	74·6	0·88	19·5	61	464	57	72·6	79·9	0·90	18	55	432	69	67·5	77	0·88	11·2	14·5	460	63	72	80·9	0·89	16	43
	500	315	38	46·6	58·9	0·86	27	61	358	47	54·8	64·8	0·85	23·5	64	326	49	55	67	0·82	14·5	29·5	315	51	57	66·9	0·86	19·5	46

* Broke on being reloaded after proof-stress determination
† 0·2% set

Samples tempered for 60 min

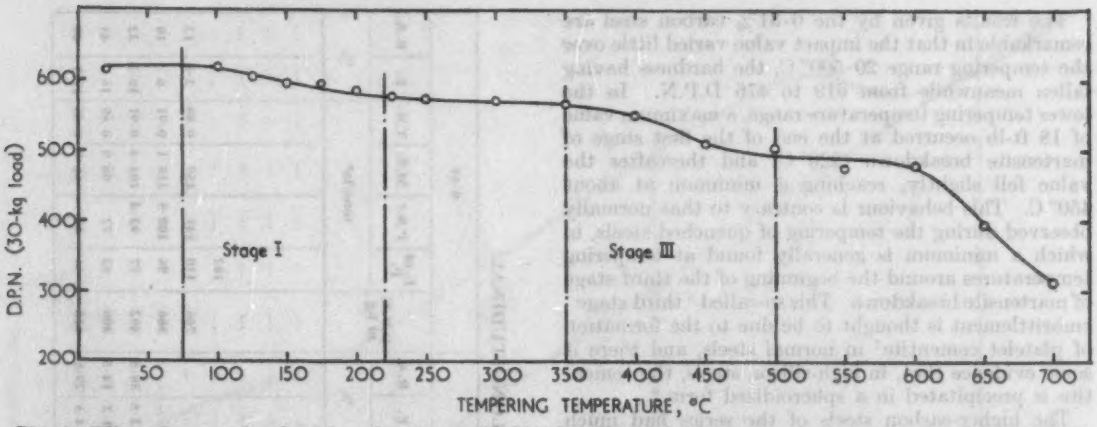

Fig. 4—Effect of tempering for 1 h on hardness of 0·31%C–1·97%Si–0·84%Mo steel, water-quenched from 970° C

machine fitted with a modified anvil,[10] previously designed for high-temperature tests.

Measurements of the energy absorbed in fracturing the test piece and of elongation after fracture were made. The hardness of each specimen was measured as a check on the heat-treatment. Table V records the results obtained. The D.P.N. values are not reproduced as they agreed closely with those of previous test-pieces similarly heat-treated.

In the untempered condition, the effect of increasing the carbon content from 0·31% to 0·61% was to reduce drastically both the energy absorption and ductility of the specimens. Low-temperature tempering, up to 150° C, had little effect on the steels containing 0·31% and 0·41% carbon, the energy absorption and ductility of which were high. The effect on the two higher-carbon steels was more marked and resulted in a threefold increase in energy absorbed during fracture. Further raising the tempering temperature resulted in a lowering of the energy absorbed by the two lower-carbon steels and a concomitant increase in ductility, in spite of the fact that the end of the first stage of martensite breakdown (about 220° C) had not been reached. The two higher-carbon steels behaved in a more normal manner and continued to show a rapid increase in energy absorption up to the end of the first stage of tempering.

ABRASION TESTS

Through the courtesy of Mr. W. B. Wragge a series of abrasion tests was carried out on samples of three of the four steels, water-quenched and tempered at various temperatures.

The method of testing was similar to that adopted by Suzuki[11] in Japan and Chernyshev[12] in Russia. It consisted in essence of a rotating, loaded, steel tube (0·498 in. o.d., 0·25 in. i.d.) in contact with the specimen under test.

The specimen itself was mounted on a table, the angular movement of which was transmitted to a hydraulic dynamometer which measured the torque generated by the friction between the rotating steel tube and the test specimen. The rubbing surface was cooled by an air blast (at about 12 lb/in² pressure) which also removed dust formed during the test. Arrangement was also made for varying the load on the rotating standard and for counting the revolutions made during any one test. In the series of tests under discussion, the loading used was 342 lb/in², the rubbing speed 214 rev/min (giving a peripheral speed of 28 ft/min and a bore speed of 14 ft/min), and each test ran for 2000 revolutions. The standard cylinders and test samples were weighed to an accuracy of ±0·0005 g before and after test, the loss in weight after testing being a measure of the wear.

The summarized results are given in Table VI from which the following general conclusions may be drawn:

(*a*) Silicon steels seem to be considerably superior to the plain carbon steel. This is in agreement with the conclusions reached by Suzuki who found that Si–Mn steel was more abrasion-resistant than other steels of low silicon content.

(*b*) Carbon content at any particular hardness level (cf. the three Si–Mo steels tempered at 700° C) appears to be the main factor controlling wear resistance, and the higher the carbon content, the lower the wear under given conditions.

CONCLUSIONS

From the results of mechanical and other tests carried out on a series of experimental Si–Mo steels, with carbon contents ranging from 0·31% to 0·61%, it appears that some promising properties can be developed in these steels by heat-treatment.

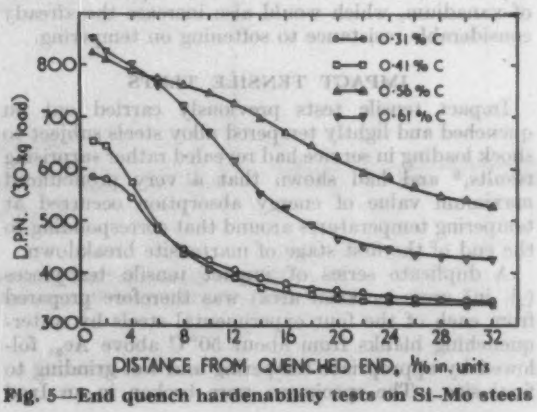

Fig. 5—End quench hardenability tests on Si–Mo steels

Table IV

EFFECT OF TEMPERING ON CHARPY IMPACT VALUES OF WATER-QUENCHED Si-Mo STEELS

Carbon, %	0·31		0·41			0·56			0·61	
Tempering Temp., °C	ft-lb W.Q.*	D.P.N. 30 kg	ft-lb A.C.†	ft-lb W.Q.	D.P.N. 30 kg	ft-lb A.C.	ft-lb W.Q.	D.P.N. 30 kg	ft-lb W.Q.	D.P.N. 30 kg
20	14·3	619	4·5	...	690	1·1	...	830	1·2	867
100	15·0	623	4·5	...	680	1·4	...	823	1·2	860
125	15·0	606	5·7	...	672	2·2	...	804	1·3	829
150	15·6	591	6·2	...	669	2·3	...	783	1·9	814
175	16·0	589	7·6	...	653	2·5	...	755	2·4	790
200	16·4	581	9·4	...	633	2·2	...	730	2·7	772
225	18·1	571	9·8	...	625	2·3	...	720	3·2	739
250	17·1	569	10·3	...	618	3·0	...	700	3·6	738
300	16·0	565	11·4	...	617	4·5	...	692	4·1	732
350	16·6	557	11·3	...	605	4·1	...	668	4·7	718
400	17·8	524	11·4	...	579	4·9	...	633	5·3	666
450	16·3	483	10·4	10·5	524	5·7	6·2	564	6·0	583
500	17·5	476	10·5	11·6	516	7·7	8·3	542	6·7	564
550	20·0	464	10·7	12·1	505	9·6	10·0	533	7·7	539
600	21·7	458	11·3	12·5	495	10·1	12·6	497	8·0	492
650	32·1	376	11·9	15·2	437	14·3	16·9	430	10·8	402
700	45·4	308	22·7	33·1	346	16·2	27·7	326	16·2	325

Specimens 10 × 10 × 56 mm with standard Izod notch. Tempered for 60 min.
* Water-quenched from tempering temperature
† Air-cooled from tempering temperature

As would be expected from the compositions used in this experimental work, the hardenability of the materials is not high, though through-hardening was obtained in 1·6-in. diameter specimens by water-quenching.

A remarkable property of these steels was their great resistance to softening or tempering at temperatures up to 600° C. In the case of the 0·31% carbon steel, the hardness dropped from about 600 D.P.N. in the as-quenched condition to only about 475 D.P.N. after one hour's tempering at 600° C. The drop in hardness of the other steels of the series, which had higher initial hardnesses, was correspondingly greater, but in no case was a hardness of less than 500 D.P.N. recorded. Tempering at higher temperatures resulted in a rapid softening of all the steels which had D.P.N. values of approximately 300 after 1 h at 700° C.

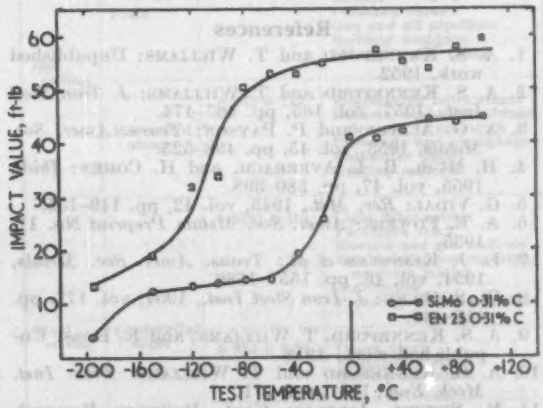

Fig. 6—Comparative results of sub-zero impact tests on B.S. En.25 and Si-Mo steel, quenched and tempered to give a D.P.N. of approximately 300

Two factors account for the resistance to softening on tempering:

(i) Silicon raises considerably the temperature at which martensite finally decomposes into ferrite and cementite (end of third stage of tempering)

(ii) Molybdenum, whilst having little effect on the temperature at which martensite breaks down, delays softening by the formation of complex carbides, which then give rise to secondary hardening effects.

As a result of their resistance to tempering all the four steels possessed high tensile strengths after heat-treatment. In the case of water-quenched samples tempered for 1 h at 600° C, the maximum stress ranged from 92·6 tons/in² (0·31% C) to 101·4 tons/in² (0·61% C) with a yield ratio of 0·9 and a corresponding reduction in area of 59–32%. Tempering for 1 h at 700° C reduced the maximum stress to 61–67 tons/in² and increased the reduction in area to 61–46%.

The Charpy impact test results on these steels were interesting in that the embrittlement usually found in quenched steels after tempering at around 350° C (the so called 'third stage embrittlement') was absent, though a slight drop occurred on tempering at 500–550° C (end of third stage of martensite breakdown in these steels). This effect is presumably due to the fact that cementite, when precipitated during the tempering of high-silicon steels, tends to form as spheroids rather than platelets. In the case of the 0·31% carbon steel, the Charpy impact value was remarkably constant up to tempering temperatures of 500° C, being about 14–17 ft-lb.

As would be expected from the known effect of silicon on impact-transition temperature, the low-

Table V

IMPACT TENSILE PROPERTIES OF WATER-QUENCHED AND TEMPERED Si-Mo STEELS

Carbon, %	0·31		0·41		0·56		0·61	
Tempering Temp., °C	Energy, ft-lb	Elong., %	Energy, ft-lb	Elong., %	Energy, ft-lb	Elong., %	Energy, ft-lb	Elong., %
20	74·5	13	74·5	10	...	...	5	0·5
100	76	13·7	81	10·5	14·5	1	12	1
125	...	...	82	12	17	1·7	13·5	1
150	76	15	83·2	12·5	46	4·5	15	1·5
175	70·7	14·7	79	13	84·5	7·5	19	2
200	69	15·2	75·7	13	87	10·5	49·5	3
225	66	15	74	13·2	86	10·2	74	7
250	66	14·5	72	13	84	10·2	72	7·5
300	61	14·5	67	12·5	80·2	10·7	68	7·5
350	60	13·5	63·5	12·2	75	11·5	63·7	7·5
400	59	14·2	62·5	13	67	12·5	56	7·7
450	57·5	14·2	61	14	65	13	55·2	10·7
500	54·5	15·5	58·5	14·5	64·5	13·5	55·5	11·5
550	57	17	60	15·5	65·7	14·2	55	12·5
600	55	18	59·7	16	65	16	54·2	13·5
650	54·7	20·5	59·5	17	64	18·7	54·7	15·5
700	54·5	25·5	54	22·5	...	...	55·5	22·5

Tempered for 60 min

temperature impact properties of the 0·31% carbon steel were greatly inferior to those of an En.25 steel of similar carbon content, heat-treated to give a similar hardness (approximately 300 D.P.N.). The room-temperature impact properties of the Si–Mo 0·31% carbon steel in the as-quenched or lightly tempered condition were, however, considerably better than those of the En.25 material. Similar remarks apply to the impact tensile properties of the 0·31% carbon experimental steel.

Table VI

WEAR TESTS ON Si-Mo STEELS

Steel	Tempering Temp., °C	Loss in Weight, g	D.P.N. 30 kg
Si–Mo 0·3% C	20	0·0015	618
	220	0·002	575
	350	0·0025	484
	700	0·511	341
Si–Mo 0·4% C	20	0·001	644
	220	0·0015	614
	350	0·002	579
	700	0·3115	344
Si–Mo 0·6% C	20	0·001	842
	220	0·001	752
	350	0·0025	720
	700	0·065	343
Si–Mn 0·6% C	20	0·001	736
	220	0·002	680
	350	0·002	644
	700	0·3920	265
0·6% C	20	0·0042	798
	220	0·002	579
	350	0·160	449
	700	0·8402	206

Further work is in progress on the fatigue properties (push-pull) of some of these materials in various states of heat-treatment, with the object of determining whether the optimum combination of hardness, strength, and ductility produced by tempering at the end of the first stage is reflected in the fatigue limit.

Acknowledgments

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Flat Rolling

THE EFFECT OF PLANT DESIGN AND LAYOUT ON CAPITAL AND OPERATING COSTS

By W. F. Cartwright, D.L., M.I.Mech.E., and M. F. Dowding, M.A., M.I.Mech.E.

SYNOPSIS

Four typical installations for producing flat rolled products are considered. The qualities and grades of products are defined and it is shown that the use to which the end product is put defines the combination of these. As no one plant can produce the full range of qualities, the limitations of each are shown. The metallurgical factors involved and their influence on the end product are discussed. The operating costs of each plant are also tabulated.

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THE PROBLEM OF FLAT ROLLING

Products

FLAT-ROLLED PRODUCTS are classified as detailed in Table I.

Quality

Characteristics—The products are required to meet specifications of (*a*) surface, (*b*) ductility, (*c*) strength in two directions, and (*d*) shape.

Grades—The above characteristics are called for in various combinations to varying degrees depending on the end use of the product. Table II demonstrates this.

Table I

FLAT-ROLLED PRODUCTS

Process	Product	Thickness, in.	Uses
Hot rolling	Plate	0·119 and above	Engineering fabrications Shipbuilding Boilers Pressure vessels Gas and oil pipelines Railway waggons Oil and water tanks
	Hot-rolled sheet	0·047–0·119	Engineering fabrications Chassis, wheels, and brake drums. Drum stock Pressings and stampings Rainwater goods Roofing material
Cold rolling	Cold-rolled sheet	0·0295–0·101	Light fabrications Furniture stock Electric and gas cookers Refrigerator and washing-machine bodies Autobodies Pressings and stampings
		0·014–0·0295	Drum stock Enamelling stock Galvanising stock
		0·008–0·014	Tinplate Blackplate Enamelling stock

There is not as yet an agreed scale of ductility but the figures for $\frac{1}{2}$-in. wide test pieces given in Table III are typical of deep-drawing steels.

Operational Considerations

The rolling of products from a slab is primarily a metallurgical problem and the degree of success with which the highest grades can be produced depends, therefore, on the extent to which optimum conditions can be achieved in each phase of the operation.

Layout

Continuous Mills—As will be seen later, the temperatures at which the strip receives its last reduction and at which it is coiled have an important bearing on the mechanical properties of the end product. The temperature of the last pass is controlled by delaying the breakdown at the entry to the finishing train so that the strip reaches the last stand within the defined temperature tolerances. The coiling temperature is achieved by a regulated cooling zone on the run-out table between the last finisher and the coilers. Both

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This paper is based on one prepared for the Latin-American Meeting of Experts on the Steel Making and Transforming Industries organized by the Economic Commission for Latin America in São Paulo in October, 1956. In the original paper comparisons were also made with operations on mechanized sheet and tinplate mills but as it is unlikely that this method will be adopted for new installations in Europe it has been omitted to shorten and simplify the paper. Sections describing the various processes in detail have also been omitted for the sake of brevity.

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Table II

REQUIREMENTS FOR FLAT-ROLLED PRODUCTS

Characteristics	Requirement	Examples of (i) High and (ii) Low Grades
(a) Surface	Smoothness, freedom from defects either visible as rolled, or subcutaneous and liable to show up after drawing	(i) Autobody sheet in which surface must be perfect but if too smooth (slick) drawing is difficult (ii) Galvanizing stock, e.g. for bucket manufacture in which surface is not so important as zinc coating covers minor defects
(b) Ductility	Clean soft steel with physical properties meeting specifications given below	(i) Autobody shaped panels, door pillars, brake drums, etc. of extra deep drawing quality (ii) Furniture stock and fabrications in which only bending is required
(c) Strength	Yield strength, impact strength, and absence of directional properties	(i) Pressure vessels, ship and gusset plates in which high yield and impact strengths are required in two directions (ii) Plates for lightly stressed fabrications such as gearbox covers not demanding high strength
(d) Shape	Accurate gauge tolerance in two directions. Flatness	(i) Autobody requires accurate gauge to ensure even drawing. Furniture stock requires flatness. All high-speed automatic processes require consistently accurate gauge (ii) Galvanizing stock and drum stock where slight gauge variations are acceptable

these factors have their effect on the layout. In the first place, a delay table must be provided between the roughing train and the finishers, and in the second place the run-out table must be of such a length that sufficient and effective cooling can be installed.

The slab must be discharged from the reheat furnace at a sufficiently high temperature to allow good reduction at the roughing mills but this leaves the breakdown temperature too high to allow correct finishing temperatures to be reached at the last finisher. Most continuous mills are therefore laid down with four roughers and six finishers with a delay table between the two.

If seven finishers are installed, a thicker breakdown could be accepted at the finishing mill, but a thicker breakdown will come hotter from the roughing mills and therefore it must be held longer on the delay table, with the result that output is not increased. The thicker, shorter breakdown, however, does result in better run-down, i.e. less variation in gauge from end to end of the coil. Some mills have been laid down with five roughers and six finishers and this has two advantages: either a thicker slab (and hence a heavier coil) can be used or the original slab can be discharged from the furnace at a lower temperature, and the delay time between roughers and finishers can be curtailed with a consequent increase in output. If it is decided to have ten mills it is therefore best to divide them into four roughers and six finishers but if eleven are chosen it is better to have five roughers and six finishers rather than four roughers and seven finishers.

Semi-continuous Mills—If lower outputs are required, a reversing rougher and continuous finishing train can be installed in place of a fully continuous mill. If the mill comprises one rougher and six finishers, the gauge variation and temperature control will be similar to those on a continuous mill but the output will be lower owing to the longer time required in the roughing train. Whereas a continuous mill can make up to 50,000 tons/week, a semi-continuous mill with six finishers could not make more than 25,000 tons/week of the same product. To reduce capital cost still further, the number of finishing mills is sometimes reduced to four and in one case to three. If the same rundown as that achieved by a continuous mill is required, the slab weight must be reduced, since the breakdown gets thinner and longer when fewer finishing stands are used. For example, for a finished hot band of 0·072 in. gauge the respective slab weights are as follows:

6 finishers	500 lb/in. width
4 finishers	220 lb/in. width
3 finishers	110 lb/in. width.

A slab weight less than 200 lb/in. width is not considered economic for further processing and therefore four finishers are regarded as the economic minimum in a semi-continuous mill.

Steckel Mill—A further attempt to reduce the initial capital cost led to the invention of the Steckel mill, in which a reversing rougher is followed by a reversing finisher and the strip is coiled in furnaces on either side of the finisher during each of the five finishing passes to avoid the temperature loss which would occur on a single-stand finisher.

Width—On a continuous mill, cross-rolling should be avoided at all costs. A slab to be cross-rolled must be short enough to go through the first rougher sideways and, to keep this first mill down to about 120 in. wide, the normal slab length of 18 ft must be halved. This operation seriously reduces the output and for this reason is not recommended. The widest slab which can be readily made without resorting to freak ingots or very high-lift slabbing mills is about 60 in., so the most convenient width for a continuous mill is 66 in. To feed an 80-in. mill with slabs which do not have to be cross-rolled, very large ingots must be used and slabs up to 74 in. wide produced on the slabber. This can be done with a universal slabbing mill or by cross-rolling the ingot.

The same limitation cannot be said to apply to a semi-continuous or a Steckel mill as the reversing rougher can be made to cross-roll without significantly increasing its rolling time. In many instances this mill, in fact, combines the duties of a reversing rougher with that of a plate mill and therefore is of adequate width to cross-roll a reasonable length of slab.

Metallurgical Factors

The most important metallurgical factors which determine the grade of finished product from a hot-strip mill are discussed below.

Slab Conditioning

The slabyards must be large enough to allow hand

Table III

MECHANICAL PROPERTIES OF DEEP-DRAWING STEELS

Quality	Hardness, Rockwell B	Yield Stress, tons/in²	Ultimate Tensile Stress, tons/in²	Elongation on 5 in., %
Extra deep-drawing quality	45–47	10–12	19·5–20·5	33–36
Deep-drawing quality	46–50	11–13	20–21	30–33
Normal	48–54	12–14	20·5–21·5	28–31

Table IV

FINISHING AND COILING TEMPERATURES

Mill Speed, ft/min	Gauge, in.	Finishing Temperature °F	Finishing Temperature °C	Coiling Temperature °F	Coiling Temperature °C
1787	0·140	1700	927	1400	760
1787	0·140	1630	888	1310	710
1715	0·140	1600	870	1290	695
1480	0·140	1700	927	1250	676
1480	0·140	1630	888	1200	649
1780	0·125	1650	899	1220	660
1680	0·125	1650	899	1190	644
1480	0·125	1650	899	1130	610
All normal speeds	0·099	All normal temps.		<1200	649

scarfing of cold slabs before feeding them to the reheat furnaces. In layouts where the slabbing mill is in line with the strip mill, ingots can be rolled directly to hot strip, which saves a reheat but as this precludes slab conditioning it results in an inferior surface on the end product and is not to be recommended.

Descaling

Proper descaling is essential for good surface condition. Four basic problems must be solved to ensure that scale is completely removed as it is formed:

(i) The atmosphere in the reheat furnace must be such as to ensure that the scale is properly formed and is easily removable at the roughing scale breaker
(ii) The descaling sprays must be correctly stationed to remove the scale as it forms, i.e. on discharge from the furnace, throughout the roughing train, and before the finishing train of a continuous mill or the equivalent positions on a semi-continuous or Steckel mill
(iii) Descaling water must be clean so that the descaling nozzles do not get blocked
(iv) Descaling water-pressure must be high enough to ensure that the impact of the water completely removes the scale.

The rate of scale formation decreases with temperature but scale removal is more difficult where rolling time is long (e.g. in Steckel mills) and the risk of rolled-in scale is thereby increased. In a Steckel mill it is also difficult to locate descaling sprays at the optimum position in the finishing mill because of the lack of space between the mill and its coilers.

Finishing and Coiling Temperature

For maximum ductility (extra deep drawing and better) both in hot-finished and cold-rolled steel, the optimum temperatures are as follows:

Finishing 1650° F (899° C)
Coiling <1200° F (649° C).

Owing to the rolling process, the attainment of these optima are interrelated because the quenching effect of the sprays on the run-out table is limited. This means that a high finishing temperature will normally lead to a high coiling temperature unless the finishing mill speed is reduced and the output rate reduced. This relation is shown in Table IV.

In general, departure from these temperatures has the following effects on the product or the process:

(i) *Plate and H.R. Sheet:* High finishing and coiling temperatures produce banded structure and, as a result, poor mechanical cross-directional properties in balanced steels, either from piling sheared plates too hot from the mill, or coiling 0·375-in. or thinner plate for subsequent shearing.
(ii) *C. R. Sheet:* High coiling temperatures cause grain growth to a point where mechanical properties suffer or ' orange peel ' occurs during pressing. Low finishing temperatures leave residual strain and result in very large surface grains which render the product unusable.
(iii) *Tinplate:* Low finishing temperatures (below 1520° F, 826° C) produce a hard strip which is difficult to reduce by cold reduction to tinplate gauges. High coiling temperatures (cf. plate) produce banded structures and the heavy cold reduction produces a deleterious directional effect in the finished tinplate.
(iv) *Pickling:* A high coiling temperature produces a tight scale very difficult to remove in the pickle line, particularly at the edges. It also increases hydrogen embrittlement when pickling strip for tinplate.

The effect of finishing and coiling temperatures on the mechanical properties of a deep-drawing steel (0·09% C, 0·41% Mn) in the hot-rolled condition are shown in Table V and are summarized diagrammatically in Fig. 1.

Directionality

Continuous rolling in one direction produces material in which the mechanical properties across the band are inferior to those in the direction of rolling. This effect is due to two causes:

(i) Orientation of grains in the direction of rolling
(ii) Elongation of impurities in the direction of rolling.

The effects of (i) can be eliminated by normalizing

Table V

EFFECT OF FINISHING AND COILING TEMPERATURES ON MECHANICAL PROPERTIES IN HOT-ROLLED CONDITION

Finishing Temperature °F	Finishing Temperature °C	Coiling Temperature °F	Coiling Temperature °C	Hardness, Rockwell B	Yield Stress tons/in²	Yield Stress kg/cm²	Ultimate Tensile Stress tons/in²	Ultimate Tensile Stress kg/cm²	Elongation, % on 8 in.
Effect of finishing temperature									
1560	849	1010	543	64	18·25	2870	24·00	3780	30·0
1610	877	1080	582	61	16·75	2635	23·15	3640	30·0
1645	896	1180	638	57	14·00	2200	21·10	3320	34·5
Effect of coiling temperature									
1610	877	1080	582	61	16·75	2635	23·15	3640	30·0
1620	882	1200	649	58	16·63	2620	23·9	3760	31·0
1608	876	1280	693	54	15·30	2405	22·15	3480	32·0
1620	882	1370	743	51	13·00	2045	19·95	3140	34·5

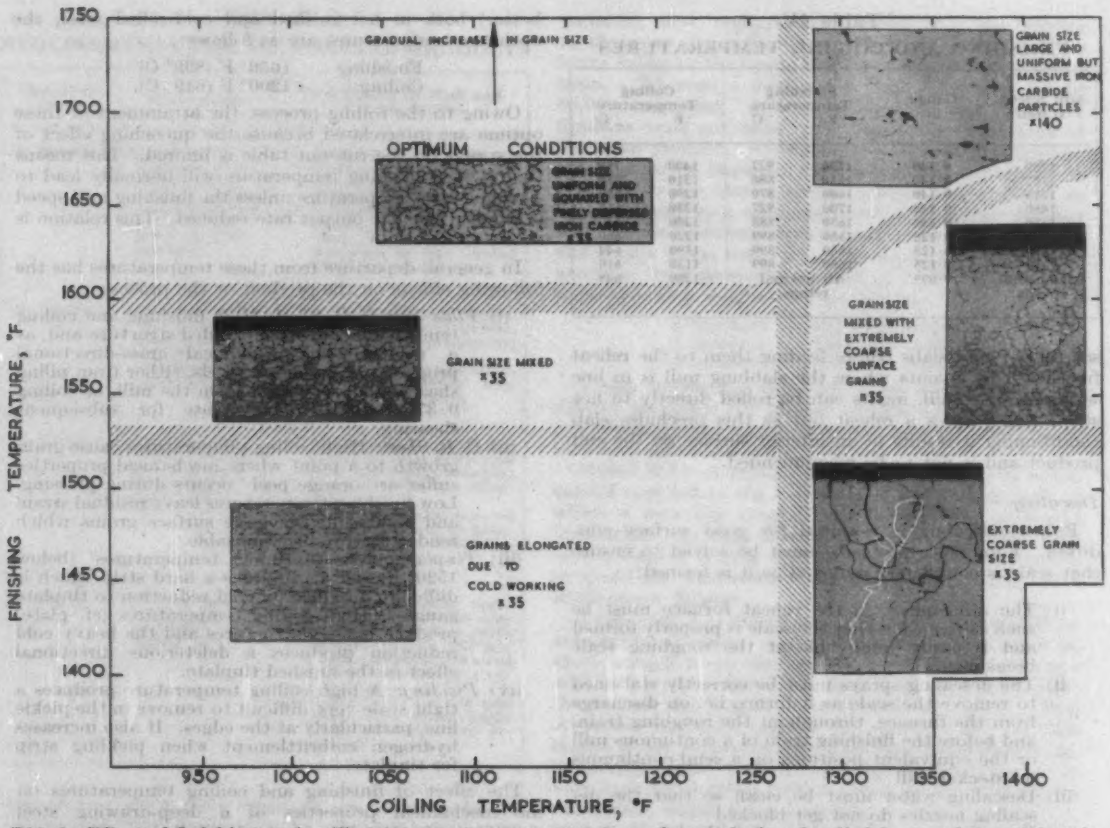


Fig. 1—Effect of finishing and coiling temperatures on structure of quenched and coiled low-carbon steel strip

but the effects of (ii) can be removed only by cross-rolling. Cross-rolling in a continuous mill brings the disadvantage of using short slabs with consequent loss of yield and output. In reversing mills this disadvantage is less pronounced. Directionality is not marked in cold-reduced sheets.

Roll Condition

Centre and Crown: It is axiomatic that a thin piece of flat material cannot be elongated by rolling without tension unless the thickness at the centre is greater than the edges. For this reason in all flat rolling mills the roll camber must be preserved to produce a shape at each stage suitable for the next stage in reduction. In mills where the repeated use of one stand is necessary (e.g. Steckel or semi-continuous strip mills) the shape of the finished product must be worse than that from a continuous mill.

Scale Pattern: If descaling is ineffective at any point, the next pair of rolls will pick up a scale pattern as the scale is rolled into the strip and this pattern will be impressed into the strip which follows. Maximum roll changes are therefore necessary to assure the highest surface quality. Again, this problem is aggravated and is nearly insoluble where a number of passes per coil are made on one stand.

Cold Reduction: The production of thin gauges on pack mills was obtained by rolling a number of sheets to the required gauge but the grain size so obtained was such that an annealing temperature of 800° C (1472° F) was needed to obtain the ductility required, but at this temperature the sheets stuck together and could not be separated after cooling. To avoid this, the phosphorus content was increased, with the result that, by modern standards, the finished sheet and tinplate was hard. It was then discovered that, by giving a 40% cold reduction to a low-carbon soft steel, small grain size was obtained which, after annealing at 665° C (1229° F) produced the perfect metallurgical condition for deep drawing.

The equipment developed for this cold reduction, viz. the 4-high mill with small work rolls, large back-up rolls, and high strip tension, is able to produce consistently accurate thin gauges at high outputs. If the total cold reduction exceeds 40%, the ductility of the end product is reduced.

Factors affecting the characteristics of each product are summarized in Table VI.

Quantity

Outputs

Four possible types of plant are discussed later for different output and product ranges. These are as given below:

	Plant	Output Slab, tons/year
1	Steckel hot strip mill and reversing cold mills	120,000–350,000
2	Semi-continuous hot strip mill and reversing cold mills	300,000–500,000
3	Semi-continuous hot strip mill and tandem cold mill	500,000–800,000
4	Continuous hot strip mill and tandem cold mills	1,250,000–2,500,000

Table VI

FACTORS AFFECTING PRODUCT CHARACTERISTICS

Product	Surface	Ductility	Mechanical Properties	Shape
Hot-rolled plate and sheet	Steel quality Slab condition Furnace atmosphere Descaling Roll condition	Steel quality Finishing temperature	Steel quality Thickness Percentage cross rolling. (Effect of unidirectional rolling can be removed by normalising if steel is clean)	Roll condition Mill spring Slab shape Temperature rundown Roll coolant
Cold-rolled sheet Blackplate	Steel quality Slab condition Furnace atmosphere Descaling Roll condition Finishing temperature Coiling temperature Pickling Annealing Temper pass Strip lubricant	Steel quality Finishing temperature Coiling temperature Percentage cold reduction Annealing Percentage temper pass	Steel quality Thickness Percentage elongation in temper mill Annealing cycle	Roll condition Rolling tension Roll coolant Strip lubricant

Tonnage Capacities and Product Limitations

It will be apparent that no one of these plants will be capable of producing the full range of products from the lowest to the highest grade. In some measure high-grade products can be produced in the low-output plants with a sacrifice of yield. Table VII shows (*a*) the tonnage of each product which can be expected from each plant from 100 tons of slab and (*b*) this tonnage expressed as a percentage of the ingot make (yield, ingot/slab, 85%). It will be noticed that there are some products in the higher-quality range which cannot be produced at all from certain plants. For reasons explained later it is inadvisable to produce plate thicker than $\frac{3}{4}$ in. in a continuous mill.

Conclusion

It is insufficient to state what tonnages are required but consideration must be given to how much of each quality is desired before a decision is made on the plant to be installed.

POSSIBLE SOLUTIONS

Table VIII lists the equipment involved in each case illustrated as follows:

Plant	Mill	Layout
1	Steckel hot mill and reversing cold mills	Fig. 2
2	Semi-continuous hot mill and reversing cold mills	Fig. 3
3	Semi-continuous hot mill and tandem cold mills	Fig. 4
4	Continuous hot mill and tandem cold mills	Fig. 5

Output Capacities

Table X shows the capacities of each scheme, both in terms of slab tonnages and finished tonnages of each product.

Description of Plant

The plant layouts and detailed equipment lists given make further description unnecessary. It will be seen that the Steckel mill and semi-continuous hot mill layouts make provision for plate rolling as well as strip rolling. On the continuous mill layout, plate up to $\frac{3}{4}$ in. thick can be rolled and coiled. Coils of this maximum thickness can subsequently be uncoiled, and sheared on the $\frac{1}{2}$-in. cut-up line shown on the layout (item 6). A piece-plate finishing end can be installed with a continuous mill for plate up to $\frac{3}{4}$ in. thick, but production of these heavier plates seriously reduces output from the strip mill and the practice is not recommended.

Tinning

Tinning equipment on the necessary scale is included in the layouts and in the capital costs for the sake of completeness. However, tinning costs and tin-yield figures are not included as they vary from one process to another and properly belong to a separate paper.

Capital Costs

Provision is included for all equipment and services within the perimeters shown but it has been assumed that the necessary services are provided up to established junction points at the perimeter.

Operational Problems

All flat rolling plants have certain problems in common which may attain such dimensions that their solution will affect the choice of site. Those requiring most serious consideration are discussed below.

Stocks

An assessment must be made of the correct level of

Table VII

EXPECTED YIELDS

Product	Plant 1	Plant 2	Plant 3	Plant 4
(a) Tonnage expected from 100 tons of slab				
Plate—				
Over 0·375 in.	80	80	80	...
0·119–0·375 in.	80	80	80	88
H.R. sheet	78	84	84	84
C.R. sheet—				
G.P.	67	74	82	85
Deep drg.	63	72	80	83
Autobody	...	70	78	81
Tinplate (sheared blackplate)	68	73	75	82
(b) Product tonnage as % of ingot make				
Plate—				
Over 0·375 in.	68	68	68	...
0·119–0·375 in.	68	68	68	75
H.R. sheet	66	71	71	71
C.R. sheet—				
G.P.	57	63	70	72
Deep drg.	54	61	68	71
Autobody	...	59	66	69
Tinplate (sheared blackplate)	58	61	64	70

Table VIII
PLANT EQUIPMENT

	Plant 1 Steckel Hot Mill and Reversing Cold Mills	Plant 2 Semi-continuous Hot Mill and Reversing Cold Mills	Plant 3 Semi-continuous Hot Mill and Tandem Cold Mill	Plant 4 Continuous Hot Mill and Tandem Cold Mills
Hot mill	84-in. reversing roughing stand 66-in. reversing Steckel finishing stand with 2 slab reheating furnaces 1 coiler	110-in. reversing roughing stand 5 66-in. finishing stands, with 2 slab reheating furnaces 1 coiler	110-in. reversing roughing stand 66-in. non-reversing roughing stand 6 66-in. finishing stands with 3 slab reheating furnaces 2 coilers	80-in. fully continuous hot mill 4 roughing stands and 6 finishing stands with 5 slab reheating furnaces 3 coilers
Pickling	1 pickle line	1 pickle line	1 pickle line	3 pickle lines
Cold reduction	1 66-in. reversing cold mill for sheet 1 42-in. reversing cold mill for tinplate	1 66-in. reversing cold mill for sheet 2 42-in. reversing cold mills for tinplate	1 66-in. four-stand tandem cold mill for sheet and tinplate	1 80-in. three-stand tandem cold mill for sheet 1 56-in. four-stand tandem cold mill for sheet and tinplate 1 42-in. five-stand cold mill for tinplate
Cleaning tinplate	1 cleaning line	1 cleaning line	1 cleaning line	3 cleaning lines
Annealing equipment	5 furnaces and 15 bases	7 furnaces and 21 bases	11 furnaces and 33 bases	42 furnaces and 126 bases
Tempering	1 66-in. single-stand temper mill for sheet 1 42-in. single-stand temper mill for tinplate	1 66-in. single-stand temper mill for sheet 1 42-in. single-stand temper mill for tinplate	1 66-in. single-stand temper mill for sheet 1 42-in. two-stand temper mill for tinplate	3 80-in. single-stand temper mills for sheet 1 56-in. single-stand temper mill for sheet 3 42-in. two-stand temper mills for tinplate
Tinplate finishing	2 tinplate cut-up lines 9 hot-dip tinning machines with automatic feeds and classifiers	2 tinplate cut-up lines 12 hot-dip tinning machines with automatic feeds and classifiers	3 tinplate cut-up lines 14 hot-dip tinning machines with automatic feeds and classifiers	4 tinplate cut-up lines 3 coil preparation lines 16 hot-dip tinning machines with automatic feeds and classifiers 3 electrolytic tinning lines
Cold-rolled sheet finishing	1 sheet cut-up line	2 sheet cut-up lines	3 sheet cut-up lines	8 sheet cut-up lines
Plate finishing	1 plate finishing line	1 plate finishing line	1 plate finishing line	1 ½-in. cut-up line
Hot-rolled sheet finishing	1 coil skin pass mill 1 ½-in. cut-up line	1 coil skin pass mill 1 ½-in. cut-up line	1 coil skin pass mill 1 ½-in. cut-up line	1 coil skin pass mill 1 ½-in. cut-up line

stock to carry at each stage of the process. The locations of these stocks are (*a*) slabyard, (*b*) pickle lines, (*c*) cold reduction mills, (*d*) annealing bay, (*e*) cleaning lines, (*f*) temper mills, (*g*) cut-up lines, (*h*) warehouse.

No logical figures are available to establish the tonnages at each point but it has become customary to plan for one week's output in front of each unit. In the case of the slabyard, space must be available for sorting slabs into schedules and the amount depends upon the number of grades of steel used. Additional space is required to allow hand scarfing.

Water

This is the most serious problem of all in siting a strip mill. If the plant is located near an unlimited source of soft, clean, fresh water there is no problem. In any other circumstances very careful planning of the available water must be done with the following considerations in mind.

A modern strip mill with increasing demands for a high-quality product must have adequate supplies of clean water and for many processes the water must also be soft. If the water available does not meet these conditions it must be treated to ensure the greater cleanliness and degree of softness required. Three main grades of water are required, as follows:

Grade	Quality	Specification	Use
1	Normal clean service water	Suspended solids < 25 p.p.m. with reasonably low chlorides	General-purpose cooling
2	Very clean water	Suspended solids < 15 p.p.m., chlorides < 200 p.p.m.	Hot mill descaling, finishing mill roll coolant, bearing cooling, gas seals, air compressor, motor room and general electrical cooling systems, pickle lines
3a	Soft water	Under 4° hardness	Reheating furnace cooling,* continuous pickle line rinse tanks, cold reduction mill coolant and rolling oil solutions
3b	Soft water further treated to under 1° hardness		Boiler plant for steam generation

* Harder water can be used for this application provided that the rate of circulation is kept very high.

A continuous mill working where scarce water conditions require maximum recirculation must install a central clarification and filtration plant designed to yield water with suspended solids below 15 p.p.m. This capacity will depend on the availability of make-up water under drought conditions.

Table IX shows the main circulating-water distribution for a continuous strip mill processing 2·5 million ingot tons/year.

Maintenance and Spares

It is, of course, quite uneconomical to install units in

Table IX
MILL WATER DISTRIBUTION

Part of Plant	Duty	Quantity in Circulation, gal/min.	Applied Pressure, lb/in²	Make Required, gal/min			Remarks
				Grade 1	Grade 2	Grade 3	
Slabbing mill	Scale flushing	7500	10				Recirculated via scale pit
	Descaming machine	4300	130 and 45	270			Recirculated via scale pit
	General cooling	2200	45				Returned via scale pit Provides makeup for above
Hot strip mill	Finishing-mill roll coolant	10,000	175		550		Returned via scale pit
	Descaling sprays	3300	1250		250		Returned via scale pit
	Run-out table sprays	12,500	70 and 10	500			
	General cooling	3700	45	980			Includes total-loss systems and general make-up
	Slab reheating furnaces	12,000	100			350	Recirculated in closed system; Grade 2 used in emergency
Cold	Continuous pickling	1000	45		850	150	Neutralized. Returned to main works system in emergency
	Cold reduction mills	7500	120			150	
	General purpose	3000	45		1250		
Boiler plant	Steam generation	700	175			700	Fully treated water
Totals				1750	2900	1350	

It can be seen that normal minimum make-up flows are 1350 gal/min for Grade 3, 4650 gal/min of service water of which 2900 gal/min must be to Grade 2 specification. Under drought conditions water can be reclaimed from the pickle-line system to reduce the total make-up of Grades 1 and 2 waters from 4650 to 3800 gal/min.

excess of output demands to act as stand-by. It is also impossible to maintain any unit while in production. The correct solution is to adopt a system of staggered scheduled stops for each unit and to concentrate the maintenance staff on each unit as it is stopped. Spares levels are a function of the design of machines and safe levels can only be accurately assessed after the plant has been operating some time. For the purposes of capital costs these have been set at 10% of mechanical and 15% of electrical equipment.

Scheduling

It is impossible to roll more than a certain tonnage of a given width on a hot strip mill before changing to another size if good shape and economic roll life are to be achieved. The normal practice, known as 'cutting out,' is to roll several hundred tons of the narrowest order and then increase in width by 2-in. steps to maximum width, and come down again in steps as the rolls become worn. This practice presupposes that on a continuous mill the finishing work-rolls and those of the third and fourth roughing stands are changed once per shift. Thermal equilibrium is obtained by the use of roll coolant to avoid roll crowns building up because of the heat of rolling. Attempts to standardize widths and get long runs of one size are an advantage in increasing production up to the limit where an undue number of roll changes becomes necessary to maintain good shape.

Rundown

This is the variation in gauge of hot-rolled strip due to the temperature difference between the front and back ends of the slab caused during its elongation in the roughing mill up to the point where it enters the finishing train.

On continuous mills this varies from 0·005 in. to 0·007 in. and on semi-continuous mills from 0·007 in. to 0·010 in. On a Steckel mill, owing to the coiling process, the ends are up to 0·014 in. thicker than the middle of the coil.

This variation of gauge between one end of a hot coil and the other becomes a serious disadvantage when the coils are welded end-to-end in the pickle line before cold rolling, since a thin end is welded to a thick end and a sudden change of gauge is presented to the cold mill in subsequent cold reduction. If the whole off-gauge part were cropped at the pickle line the resulting loss of yield would be unacceptable.

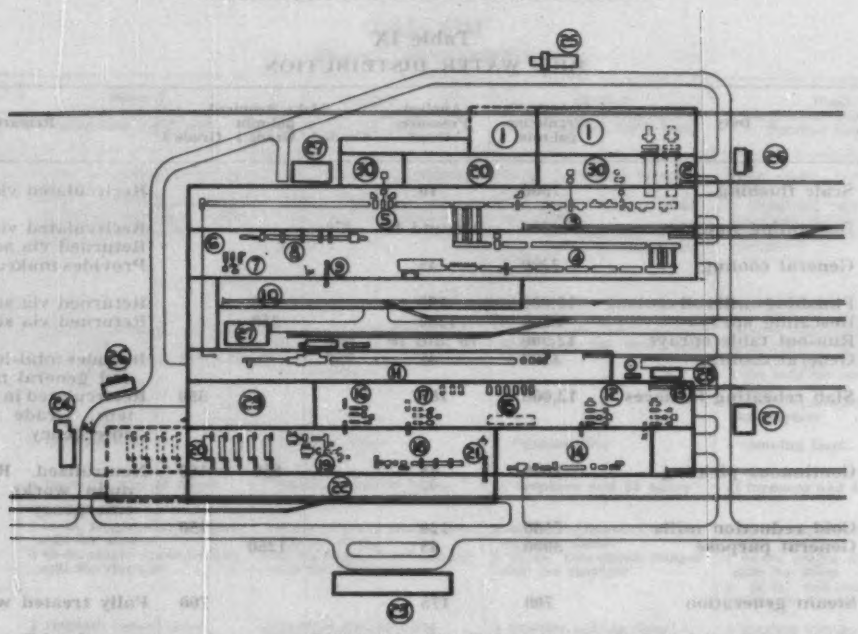
Limitations of Steckel Hot Strip Mill

The use of a hot reversing finishing mill leads to the following faults in the hot coil:

(i) Irregular gauge due to run-down described above
(ii) Bad surface and irregular shape due to the use of one pair of rolls for five finishing passes
(iii) Flecked scale due to the difficulty of descaling between coiling furnaces and mill.

Some attempt has been made to reduce flecked scale by holding the breakdown and finishing at a lower temperature but this has the double result of producing inferior mechanical properties and the pickling process is made more difficult because there is more time for scale to form in the mill.

The gauge variations inseparable from the process mean that hot-rolled coils from a Steckel mill cannot be rolled on a tandem cold mill. A reversing cold mill can, however, accept Steckel H.R. coil and reduce it successfully as the gauge variations can be made to match the normal variations of a reversing cold mill. The cost of this in yield has been shown earlier. The surface condition means that no C.R. sheet better than G.P. or



1. Slabyard
2. Slab reheat furnaces
3. Reversing roughing and plate mill
4. Plate-finishing equipment
5. Steckel mill
6. Coil conveyor
7. Coil skin pass mill
8. Hot sheet cut-up line
9. Re-squaring shear and oiling line
10. Hot sheet and plate despatch
11. Pickle line
12. Reversing cold mill for cold-rolled sheet
13. Reversing cold mill for tinplate
14. Cleaning line
15. Annealing furnaces
16. Temper mill (tinplate)
17. Temper mill (cold-rolled sheet gauges)
18. Sheet cut-up line
19. Tinplate cut-up lines
20. Hot-dip tinning machines
21. Re-squaring shears and oiling line
22. Cold-rolled sheet and tinplate despatch
23. Main office block
24. Cold-mill offices
25. Hot-mill offices
26. Boiler houses
27. Electrical sub-stations
28. Inert-gas plant
29. Roll shops
30. Motor rooms

Equipment shown dotted need not be included initially

Fig. 2—Layout of Steckel hot mill and reversing cold mills (plant 1)

drum stock can be made from a Steckel hot band but C.R. tinplate can be successfully rolled, again with some loss of yield.

For special steels and alloys such as stainless, silicon, titanium, etc., many of the above criticisms do not apply. In fact, where more than five or six passes in the finishing mill are required, a continuous or semi-continuous hot strip mill would be hopelessly uneconomic in view of the number of finishing stands needed, so that a Steckel mill is the only solution for producing hot rolled coils of these materials.

Limitations of Semi-continuous Hot Strip Mill

In this layout (*a*) the roughing time is longer and (*b*) the same work rolls take all five roughing passes. The result is that the rundown is rather greater and the surface condition of the hot-rolled strip slightly inferior. This last condition could be improved by changing rolls more often on the reversing rougher, but this would result in lower output rates and a consequent increase in operating costs.

The ultimate maximum tonnage of a semi-continuous mill is established by the time cycle at the rougher. This can, of course, be reduced (with improved rundown) if a smaller slab is used. On the other hand the use of a smaller slab reduces coil size and tends to reduce yield at the cold mill because of more frequent welds and consequent off-gauge material.

Limitations of Continuous Hot Strip Mill

The only limitation on a continuous mill is its inability to produce plate with transverse properties (through the absence of cross rolling) and the severe reduction in its output rate if plate thicker than 0·375 in. (the thickest that can be coiled) is produced. It is therefore recommended that no thicker plate is rolled and the unidirectional properties inherent in the process are removed by normalizing. The installation of one wide roughing mill to make plate is not economically justified in this case.

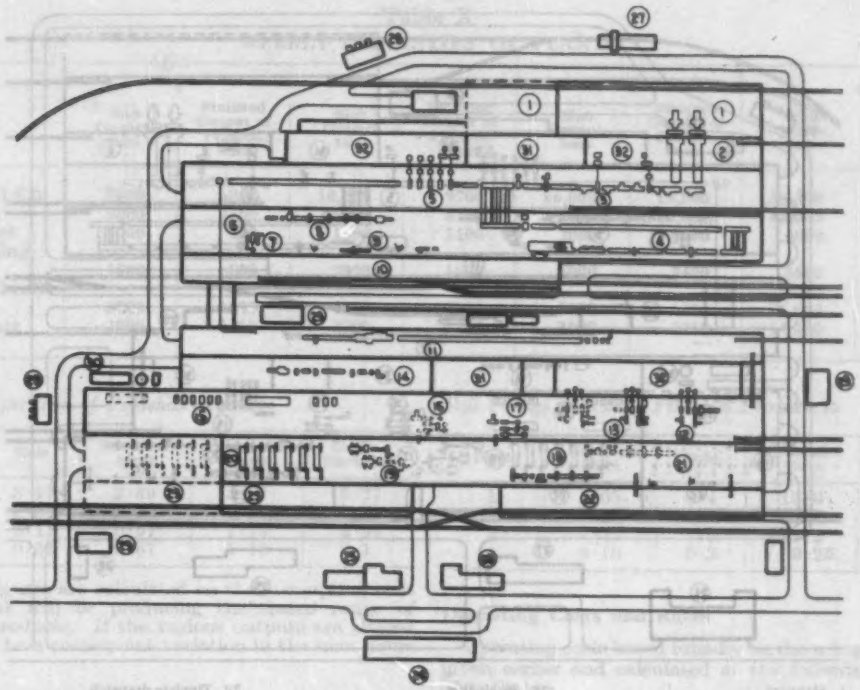
Fly Shearing

Hot-finished sheets can be obtained either by fly shearing at the finishing train or coiling and subsequent shearing. For extra deep-drawing quality, flying-sheared sheets must be cooled quickly and sheets cut cold from coil must be normalized. The flying shear limits the finishing speed and reduces output.

Limitations of Reversing Cold Mills

Although excellent for low outputs (e.g. sheet 30 tons/h, tinplate 10 tons/h) reversing cold mills give low yields because of heavy tail ends, and gauge variations are greater than on tandem mills, owing to the repeated acceleration and deceleration periods which occur at every pass instead of only once on a tandem mill. This disadvantage will be reduced when automatic gauge control is installed.

To obtain the necessary reduction from H.R. coil to sheet in three passes and tinplate in five passes, the interstand tension of a tandem mill has to be supplied by tension between the reversing mill and its coilers. The finished coil is therefore wound under a higher tension than one from a tandem mill. This does not matter in the



1. Slabyard
2. Slab reheat furnaces
3. Reversing roughing and plate mills
4. Plate-finishing equipment
5. Finishing stands
6. Coil conveyor
7. Coil skin pass mill
8. Hot sheet cut-up line
9. Re-squaring shears and oiling lines
10. Hot sheet and plate despatch
11. Pickle line
12. Reversing cold mill for cold-rolled sheet
13. Reversing cold mills for tinplate
14. Cleaning line
15. Annealing furnaces
16. Temper mill (tinplate)
17. Temper mill (cold-rolled sheet gauges)
18. Sheet cut-up lines
19. Tinplate cut-up lines
20. Hot-dip tinning machines
21. Re-squaring shears and oiling lines
22. Cold-rolled sheet despatch
23. Tinplate despatch
24. Main office block
25. Laboratory and medical block
26. Cold-mills offices
27. Hot-mill offices
28. Boiler houses
29. Electrical sub-stations
30. Inert-gas plant
31. Roll shops
32. Motor rooms

Equipment shown dotted need not be included initially

Fig. 3—Layout of semi-continuous hot mill and reversing cold mills (plant 2)

case of tinplate which is rewound on the cleaning line. In the case of sheet, however, it results in a high proportion of stickers coming from annealing to the temper mill, which either means scrapping the coil or producing sheet with surface tears after tempering. This can be avoided by re-coiling after cold reduction at a lower tension, involving extra cost, or taking a light finishing pass on the cold mill and thereby reducing output. Surface finish and shape also suffer where one pair of work rolls must of necessity be used for all passes of the cold reduction.

Limitations of Single-stand Temper Mills

All tinplate above T_2 is normally tempered by giving it two passes through a single-stand temper mill. Modern developments have led to the use of a two-stand tandem temper mill so that all tempers can be produced in one pass. Single-stand temper mills therefore have the disadvantage of low outputs on T_2 and above, and the extra coil damage inseparable from double handling of light-gauge strip coils.

Staged Development

Plant 1 can be developed to plant 2 and plant 2 to plant 3 providing sufficient room is left in the first installation to add the extra units at a later stage. Plant 4 cannot be developed from the others but the equipment used in plants 1–3 can be re-sited as a contribution to the continuous mill layout. Finishing units can be increased in capacity in each of plants 1–4 by the addition of extra identical units.

When strip tonnage requirements exceed about 600,000 tons/year it is recommended that the plate rolling be carried out separately and the roughing mill re-sited for this purpose with its plate finishing department. At this stage a new reversing roughing mill of the same width as the finisher should be installed in the strip mill.

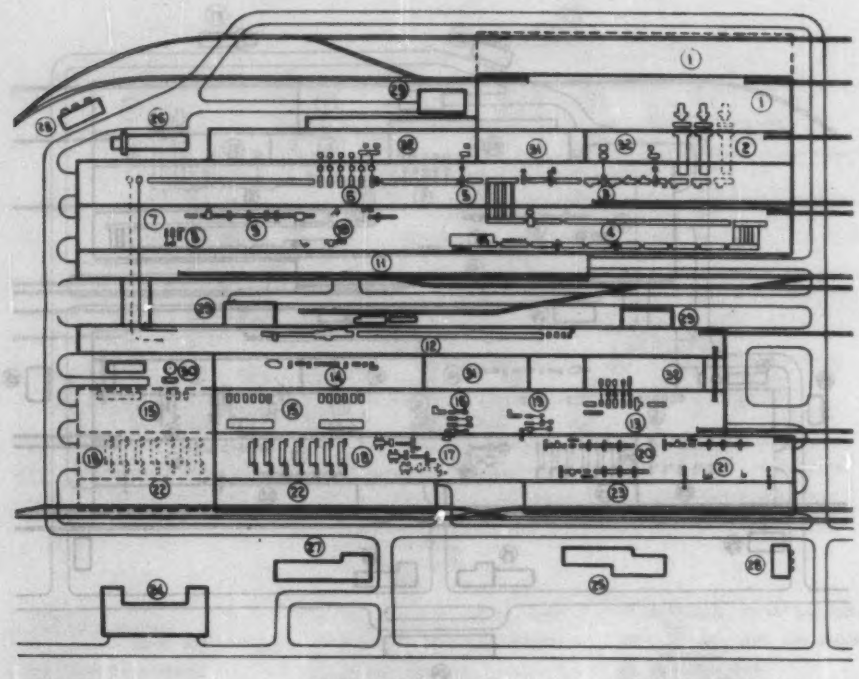
CAPITAL COSTS

Allocation of Capital Costs

The rough allocation of capital costs in millions of pounds to products, plant by plant, is shown below. The figures are based on tonnages of products given in Table X and would vary greatly if, for example, a greater percentage of tinplate was made.

Capital Allocation by Products

Plant	Plate	Hot-rolled Sheet	Cold-rolled Sheet	Tinplate	Total
1	2·6	2·3	8·0	8·85	21·75
2	3·5	2·9	12·2	11·15	29·75
3	4·0	3·3	17·0	9·70	34·0
4	2·4	3·1	35·0	25·0	65·5



1. Slabyard
2. Slab reheat furnaces
3. Reversing roughing and plate mills
4. Plate-finishing equipment
5. Non-reversing roughing mill
6. Finishing stands
7. Coil conveyor
8. Coil skin pass mill
9. Hot sheet cut-up line
10. Re-squaring shears and oiling lines
11. Hot sheet and plate despatch
12. Pickle line
13. Four-stand tandem mill
14. Cleaning line
15. Annealing furnaces
16. Two-stand temper mill
17. Coil preparation lines
18. Hot-dip tinning machines
19. Temper mill (cold-rolled sheet gauges)
20. Sheet cut-up lines
21. Re-squaring shears and oiling lines
22. Tinplate despatch
23. Cold-rolled sheet despatch
24. Main office block
25. Cold-mills offices
26. Hot-mills offices
27. Laboratory and medical block
28. Boiler houses
29. Electrical sub-stations
30. Inert-gas plant
31. Roll shops
32. Motor rooms

Equipment shown dotted need not be included initially

Fig. 4—Layout of semi-continuous hot mill and tandem cold mill (plant 3)

From the above figures the capital investment in pounds sterling per ton per year of prime product are as under:

Capital Investment per Annual Ton of Prime Product

Plant	Plate	Hot-rolled Sheet	Cold-rolled Sheet	Tinplate
1	65	61·5	85·0	130
2	43·8	52·8	84·0	117
3	33·3	39·3	53·0	86
4	15·4	16·4	30·0	43·5

Capital Charge per Ton

Calculating interest and depreciation charges at 9% per annum, capital charges per ton in pounds sterling by products are as follows:

Capital Charge per Ton for Interest and Depreciation

Plant	Plate	Hot-rolled Sheet	Cold-rolled Sheet	Tinplate
1	5·85	5·54	7·65	11·7
2	3·94	4·75	7·56	10·5
3	3·0	3·54	4·77	7·74
4	1·38	1·49	2·70	3·92

OPERATING COSTS

Yields and Usings

Yields and usings for each alternative plant are shown in the seven following tables.

Yields—Slab to Prime Finished Product and Hot-rolled Coil to Prime Finished Product

	Plate		Hot-rolled Sheet		Cold-rolled Sheet		Tinplate*	
Plant	From Slab	From Hot-rolled Coil**	From Slab	From Hot-rolled Coil	From Slab	From Hot-rolled Coil	From Slab	From Hot-rolled Coil
1	80¶	82·5	78	81	65†	68†	68	70·5
2	80¶	82·5	84	86·5	72‡	74·5‡	72	74·5
3	80¶	82·5	84	86·5	80§	83§	75	77·6
4	88**	91·5	84	86·5	82·6‖	85·5‖	82	85

* The yield to electrolytic tinplate is very slightly less than for sheared blackplate. In modern hot-dip tinning lines it is roughly 99% of primes from sheared blackplate.

† Autobody cannot be produced successfully by this process and C.R. sheet yield is low because of surface quality.

‡ Yield calculated on 20% autobody being produced.

§ Yield calculated on 50% autobody being produced.

‖ Yield calculated on 80% autobody being produced.

¶ Plate of all thicknesses (Plate mill practice: one slab—one plate).

** Plate up to ¾ in. only. (Strip mill practice: one slab—several plates.)

Table X
WEEKLY CAPACITIES OF PLANTS

	1		2		3		4	
	Slab Output, tons	Finished Output of Primes, tons	Slab Output, tons	Finished Output of Primes, tons	Slab Output, tons	Finished Output of Primes, tons	Slab Output, tons	Finished Output of Primes, tons
HOT ROLLED	7000	6800	10,000	9700	16,000	15,500	50,000	48,500
Pickling	5000	4500	6700	6100	11,000	10,000	42,000	38,000
Hot Sheet Finishing	1000	780	1300	1100	2000	1680	4500	3780
Plate	1000	800	2000	1600	3000	2400	3500	3100
COLD ROLLED								
Sheet	3000	1890	4000	2880	8000	6400	28,000	23,200
Blackplate	2000	1360	2700	1950	3000	2250	14,000	11,500

Man Hours per Ton of Finished Product

Plant	Plate	Hot-rolled Sheet	Cold-rolled Sheet	Tinplate (Blackplate)
1	3·47	2·39	3·97	5·27
2	2·36	1·17	2·29	3·73
3	2·11	0·97	1·75	2·91
4	0·56	0·67	1·18	2·1

These figures are calculated on the assumption that each plant will be producing the stated range of finished products. If the various outputs are altered there will be a consequent variation in the man hours per ton.

Heat Consumption per ton of Finished Product, 10^6 B.t.u.

Plant	Plate	Hot-rolled Sheet	Cold-rolled Sheet	Tinplate (Blackplate)
1	3·1	3·17	5·20	5·00*
2	2·8	2·65	4·35	4·36
3	2·8	2·65	3·90	4·25
4	2·25	2·37	3·45	3·60

* The heat consumption is higher for sheet than tinplate because the yield of tinplate is better than that for sheet in this process owing to surface defects.

Electricity Consumption per ton of Finished Product, kWh

Plant	Plate	Hot-rolled Sheet	Cold-rolled Sheet	Tinplate
1	160	155	325	455
2	140	126	270	400
3	140	126	215	350
4	85	90	175	275

Circulated Water Consumption per ton of Finished Product, ft^3

Plant	Plate	Hot-rolled Sheet	Cold-rolled Sheet	Tinplate (Blackplate)
1	460	495	1310	1340
2	951	920	1700	1730
3	951	920	1450	1590
4	1590	1500	2150	2200

Steam Consumption per ton of Finished Product, lb

Plant	Cold-rolled Sheets	Tinplate (Blackplate)
1	198	715
2	176	555
3	165	440
4	154	407

Roll Usings per ton of Finished Product, lb

Plant	Hot-rolled Sheet	Plate	Cold-rolled Sheet	Tinplate (Blackplate)
1	7·05	6·4	13·6	13·0
2	7·7	7·5	13·6	13·2
3	7·7	7·5	11·2	11·9
4	6·16	5·3	9·25	9·25

Operating Costs and Rates

Operating costs based broadly on the usings and yields given earlier and calculated at the following rates are given below.

The rates used were:

Labour	£0·44 per man hour (9*s.* 0*d.*)
Fuel	£0·079 per 10,000 cal (1*s.* 6*d.*)
Electricity	£0·0042 per kWh (1*d.*)
Steam	£0·782 per ton (15*s.* 7*d.*)

Cost per ton Prime Product, £

Plant	Plate	Hot-rolled Sheet	Cold-rolled Sheet	Tinplate (Blackplate)
1	43·5	43·5	52·1	57·0
2	43·3	42·2	48·9	54·5
3	43·0	42·0	46·0	51·5
4	40·5	41·2	45·0	48·3

Slab price assumed, £35/metric ton

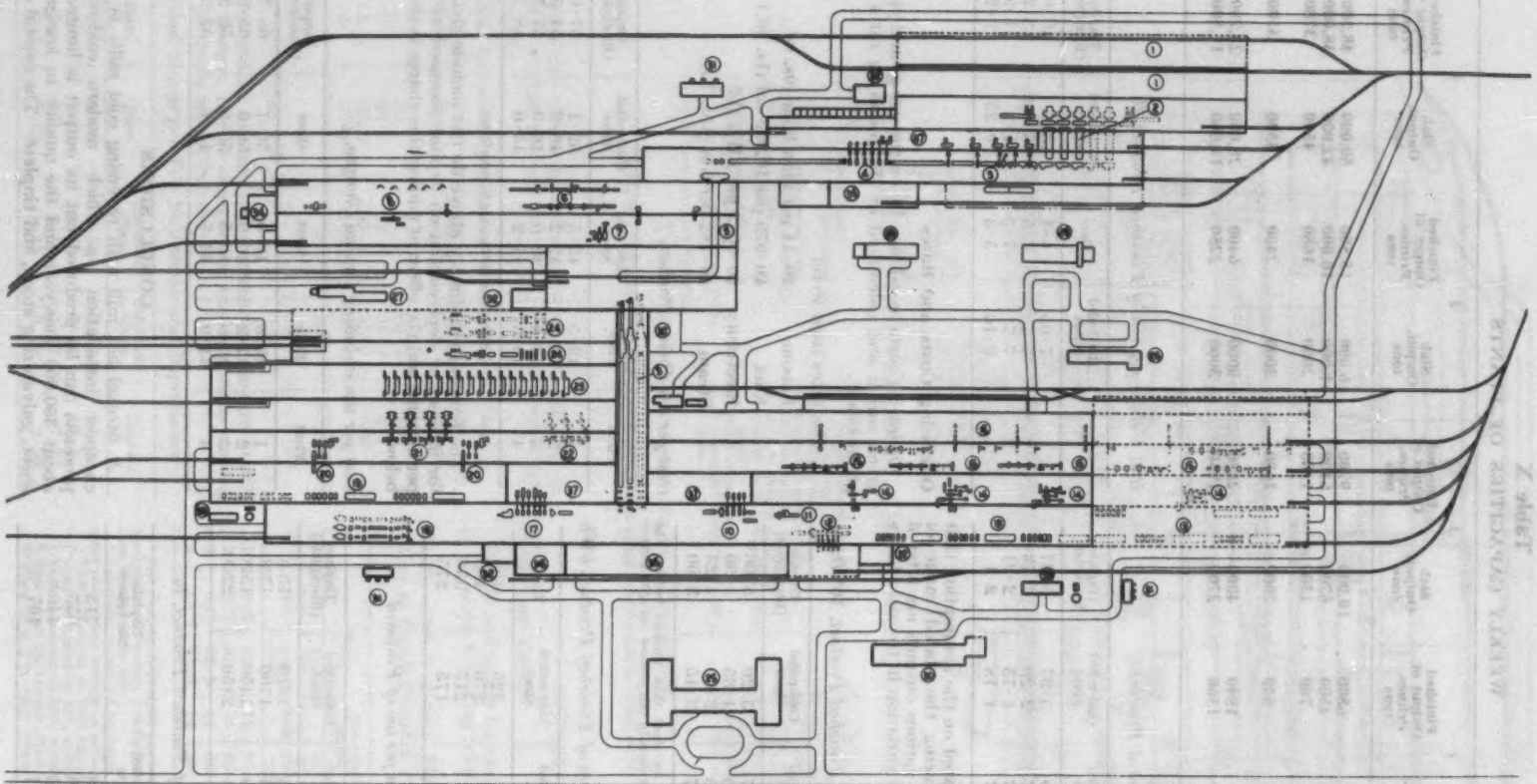
The figures immediately above do not include charges for interest or depreciation on capital (assessed at 9% per annum) and the effect of adding this charge is shown below.

Cost per ton including Capital Charges, £

Plant	Plate	Sheet	Sheet	Tinplate (Blackplate)
1	49·3	49·0	59·7	68·7
2	47·2	46·9	56·5	65·0
3	46·0	45·5	50·8	59·2
4	41·9	42·7	47·7	52·2

CONCLUSIONS

A Steckel hot mill with reversing cold mills is the cheapest installation on which modern cold-rolled products can be produced but its output is limited to about 350,000 tons/year and the quality to low-grade sheet, galvanizing stock, and tinplate. The capital cost



1. Slabyard
2. Slab reheat furnaces
3. Roughing mills
4. Finishing mills
5. Coil conveyor
6. Plate and hot-rolled sheet cut-up lines
7. Coil skin pass mill
8. Re-squaring shears, oiling lines, leveller, and hot-rolled sheet and plate despatch
9. Pickle lines
10. Three-stand tandem cold mill
11. Hand cut-up line
12. Four-stand tandem cold mill
13. Annealing furnaces
14. Temper mills
15. Cold-rolled sheet cut-up lines
16. Re-squaring shears, oiling lines, and cold-rolled sheet despatch
17. Five-stand tandem cold mill
18. Cleaning lines
19. Annealing furnaces
20. Two-stand temper mills
21. Tinplate cut-up lines
22. Coil preparation lines
23. Hot-dip tinning machines
24. Electrolytic tinning machines
25. Main office block
26. Cold-rolled sheet offices
27. Tinplate offices
28. Hot-mill offices
29. Lubricant stores
30. Laboratory and medical block
31. Boiler houses
32. Electrical sub-stations
33. Inert-gas plants
34. Hot-sheet and plate office
35. Roll shops
36. Palm oil recovery
37. Motor rooms

Equipment shown dotted need not be included initially

Fig. 5—Layout of continuous hot mill and tandem cold mills (plant 4)

Table XI
CAPITAL INVESTMENT COSTS

	Plant 1 Steckel and Reversing Mills	Plant 2 Semi-Continuous and Reversing Mills	Plant 3 Semi-Continuous and Tandem Mill	Plant 4 Continuous and Tandem Mills
		(£,000)		
(a) Structural buildings, cladding, brick buildings	2500	3500	4000	8000
(b) Building and mill utilities (including water other than process water, lighting, compressed air, fire protection, and storm sewers). Assumed to be 15% of (a)	500	500	500	1000
(c) Cranes, lift trucks, and mobile aids	500	750	1000	3000
(d) Furnaces	500	750	1000	2500
(e) Offices, amenity blocks, pay stations, sanitary facilities, and furniture	250	250	250	500
(f) Electrical equipment including switch-gear, cables, and distribution (excluding substations)	3500	4500	5000	12,000
(g) Roll shops including bearing maintenance	250	250	250	500
(h) Rolling mill and mechanical equipment including all systems and piping	5500	8500	9000	20,000
(i) Excavation and foundations for plant including all concrete work and reinforcing, site preparation excluded	4000	5250	6000	10,000
(j) Spare parts at 10% of mechanical and 15% of electrical cost	1000	1500	2000	3500
(k) Services at mechanical and electrical plant	250	250	250	500
(l) Miscellaneous and specialist	500	500	750	1500
(m) Erection of plant at 7½% of mechanical and electrical cost	750	1000	1250	2500
(n) Administrative expenses, engineering and provision for contingencies, at 15% of (a) to (m) inclusive	3000	4000	4750	10,000
Total	23,000	31,500	36,000	75,000

These costs include tinhouse and equipment; this part of capital cost is eliminated from calculations which follow for total process cost. Deductions were made as follows: Plant 1, £1,250,000; Plant 2, £1,750,000; Plant 3, £2,000,000; Plant 4, £9,500,000.

is about £23,000,000 and the product cost would be approximately as follows:

Cold-rolled sheet	£60 per ton
Blackplate	£69 per ton.

A semi-continuous hot mill with reversing or tandem cold mills would produce the full range of products of a continuous mill at some expense represented by lower yields. It combines the production of a wide plate mill and wide strip mill better than a continuous mill for outputs up to 1,000,000 tons/year of mixed products. Approximate capital costs and product costs by this method are as follows:

Output per Year, tons	Capital Cost, £m	C.R. Sheet Cost, £/ton	Blackplate for Tinplate Cost, £/ton
500,000	31·5	57	65
800,000	36	51	59

If the demand is great enough a separate plate mill and strip mill should be installed as a combination of the two has an adverse effect on both products.

For outputs in excess of 1,000,000 tons/year a continuous hot strip mill with tandem cold mills should be installed at a capital cost of about £75,000,000 giving a cold rolled sheet cost of £48 per ton and blackplate cost of £52 per ton.

Capital costs and worked examples of production costs are based on hypothetical conditions starting with a slab cost of £35 per ton.

The yields and usings shown in the tables were used for these calculations but it is emphasized that the resulting product-cost figures are hypothetical and are only given to show a comparison of costs for each case.

Anyone wishing to forecast likely product costs for a project must apply their local conditions to the yields and usings tables.

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They were able to base their estimates of typical yields, usings, and costs on the information and assistance generously supplied by these companies. The figures presented are generalized assessments of hypothetical cases and do not represent the actual operating results of any of the above companies.

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The Corrosion of Tinplate by Victoria Plum Syrup

By F. W. Salt, B.Sc., Ph.D., and J. G. N. Thomas, B.Sc., Ph.D.

SYNOPSIS

A study of the corrosion of steel by Victoria plum syrup has revealed that the syrup contains both inhibitors and accelerators of corrosion. Stannous tin inhibits the corrosion appreciably, but stannic tin slightly accelerates it. A number of possible organic inhibitors have been investigated in the plum syrup and two, caprylic and caproic acids, were found to give appreciable inhibition in the presence of 25 p.p.m. stannous tin. Caprylic acid alone in the plum syrup greatly increases the steel corrosion rate.

The corrosion of steel–tin couples with high steel/tin area ratios, such as might occur at breaks in the lacquer in cans, has also been studied in Victoria plum syrup. Very small areas of tin have been found to give appreciable protection to the steel.

Chrysanthemin, the principal colouring matter of Victoria plums, has been shown to inhibit both cathodic and anodic processes in the corrosion of steel in malic acid, but to have no significant effect on the corrosion of steel or steel–tin couples in Victoria plum syrup.

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Introduction

LOSSES OF ACID FRUITS in tin cans through hydrogen swells or perforations are still a problem, being most serious with the coloured fruits, e.g. Victoria plums and raspberries, which are usually packed in lacquered cans. As part of a programme of research into the corrosion processes in the tin can, we have previously studied the anaerobic corrosion of tin by fruit syrups.[1] It was found that the amounts of tin dissolved by yellow plums, Victoria plums, and raspberries increased in that order. The main constituent of the colouring matter of Victoria plums and raspberries is the anthocyanin chrysanthemin and this was shown to act as a cathodic depolarizer for the dissolution of tin. However, correlation of the quantities of tin dissolved with the chrysanthemin contents of Victoria plums and raspberries indicated that in both fruits other depolarizers are present. In lacquered cans, only a very small area of tin is exposed to the syrup at places where the lacquer is broken during manufacture, e.g. at the side seam and the corrugations of the can end. It is probable that the amounts of depolarizer contained in Victoria plums and raspberries are sufficient to dissolve rapidly most of the exposed tin. Data obtained by Kohman and Sanborn[2] on the corrosion of steel–tin couples in blackberry pulp indicated that tin had no appreciable effect on the corrosion rate of steel when coupled to it unless the steel/tin area ratio was less than about 20:1. It seemed, therefore, that the corrosion process at the damaged areas of lacquer on the interior of the can would consist simply of the steel base dissolving with evolution of hydrogen, in fruit syrups containing some dissolved tin. This suggested that an approach to the problem of increasing the shelf-life of cans would be to look for an inhibitor which could be added to the fruit to retard the corrosion of the steel and increase the time before sufficient hydrogen was evolved to swell the can.

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Dr. Salt is with the B.I.S.R.A. South Wales Laboratories at Swansea, and Dr. Thomas, formerly with the Association, is an I.C.I. Fellow at University College, Swansea.

Several workers[3–5] have studied the corrosion of steel in fruits with a view to correlating corrosion rates with can shelf-lives. In these experiments, precautions were not taken to prevent access of atmospheric oxygen and the observed corrosion rates were difficult to interpret since they included the depolarizing action of oxygen on the steel corrosion.[5] Thus the corrosion conditions were not the same as in the can, where the limited amount of oxygen left after evacuating is soon used up since it acts as a depolarizer for the solution of both tin and steel. The main process of steel corrosion with hydrogen evolution therefore occurs under essentially anaerobic conditions.

Very recently, Koehler[6, 7] has made a detailed investigation of the corrosion of steel and steel–tin couples in anaerobic citric acid and prune juice. In citric acid, tin coupled to steel was found to exert a greater protective action on the steel than could be accounted for by the concentration of stannous ions dissolved from the tin. The greater effect of the couple was attributed to a shift in the anodic polarization curve of steel which occurs in an unexplained manner on coupling to tin. In prune juice, the corrosion rate of steel was observed to decrease during the first day, thereafter settling down to a constant rate. Addition of stannous chloride eliminated the faster rate during the first day, the steady corrosion rate being little affected. Coupling of the steel to tin in prune juice reduced the corrosion rate considerably and this was explained as being mainly due to the ' anodic coupling shift '.

To test the effect of various inhibitors and follow the corrosion of steel under anaerobic conditions, a simple technique has been developed for measuring the hydrogen evolved over a period of several weeks from specimens of steel immersed in fruit syrup. Victoria plum syrup was used, since more of this plum is packed in lacquered cans than any other coloured fruit.

As the results for the rate of hydrogen evolution from steels in various samples of Victoria plum syrup accumulated, it became apparent that the shelf-lives of fruit packs were much longer than would be anticipated from the rate at which hydrogen would be evolved in an aggressive syrup from an area of steel likely to be exposed in the interior of a lacquered can. Experiments were, therefore, carried out to ascertain the influence of tin on the rate of corrosion of steel in plum syrup.

MATERIALS

Three different steels, in the form of bright cold-reduced strip 0·03 cm thick, were used. Their compositions are shown in Table I. The analysis for Steel 2 applies to the surface layer.

Experiments were also carried out with C20 hot-dipped tinplate which had a tin coating about 2μ thick.

For the corrosion experiments, strips 5·0 cm × 1·0 cm were used. They were degreased by swabbing with benzene and cathodically treated in 2% Na_2CO_3 at 0·05 A/cm² for 5 min. The specimens were then dipped in 50% v/v HCl for 30 s, washed with water and acetone, and weighed.

Victoria plum syrup was obtained from plums preserved in 40% sugar syrup in Kilner jars. The syrup from six jars was filtered off and mixed. After boiling for 2 min to sterilize, the syrup was stored at — 10° C until required. Four different samples of syrup were used in all. The plums from which they were prepared were grown in Gloucestershire on Pershore stock. Two samples were from the 1953 crop which had been frozen and stored. Sample *A* was bottled in November 1954 and *B* in March 1955. The other two samples were from the 1955 crop. Sample *C* was fresh fruit bottled in September 1955 and sample *D* was prepared from plums which had been stored frozen until they were bottled in April 1956. From the heights of the absorption peak at 5100Å, the chrysanthemin concentrations in the syrups *A*, *C*, and *D* were calculated to be $4·2 \times 10^{-5}$ M, $7·7 \times 10^{-5}$ M, and zero. Syrup *B* was not examined spectrophotometrically.

Table I

COMPOSITIONS OF STEELS USED

	C, %	S, %	P, %	Mn, %	Cu, %
Steel 1	0·06	0·031	0·022	0·34	...
Steel 2	0·037	0·020	0·013	0·35	0·11
Steel 3	0·08	0·03	0·015	0·38	0·11

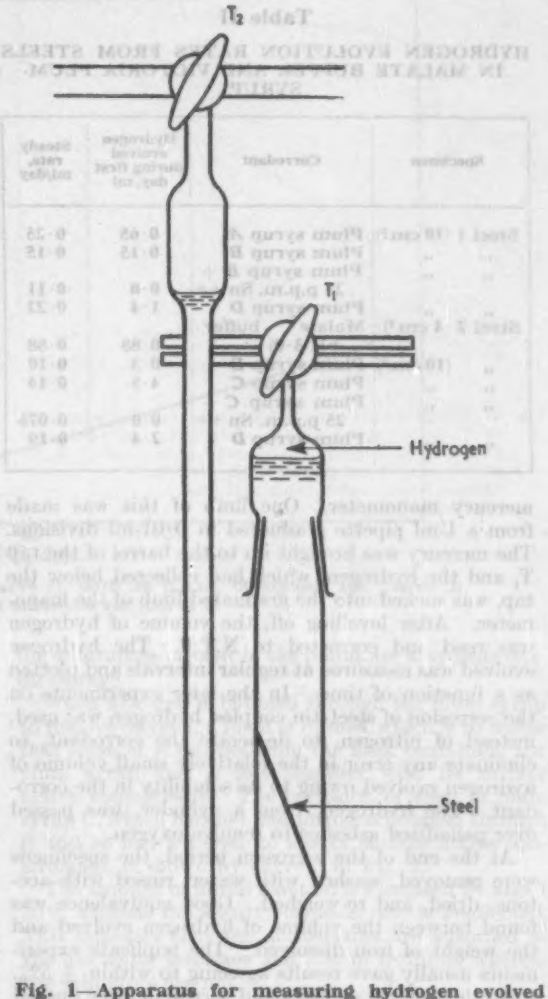


Fig. 1—Apparatus for measuring hydrogen evolved from corroding specimens

EXPERIMENTAL TECHNIQUE AND APPARATUS

The hydrogen evolved as the specimens corroded was collected in the all-glass apparatus shown in Fig. 1. Experiments were usually performed in triplicate. Three of these cells with the specimens already in position were connected via the tap T_2 to a flask containing a supply of the corrodant. Oxygen was removed by passing 'white spot' nitrogen through the cells and the corrodant simultaneously for 1 h. The corrodant was then forced under nitrogen pressure into the corrosion cells, 30 ml being placed in each cell. The limb containing the specimen was filled completely with corrodant, but a space was left at the top of the compensating limb to allow for the increase in pressure caused by hydrogen evolution. The corrosion was allowed to proceed in a thermostat held at 25·0 ± 0·1° C. To measure the hydrogen evolved, the cells were removed from the thermostat, and after flushing out the three-way tap T_1 with nitrogen, this was connected to a

Table II

HYDROGEN EVOLUTION RATES FROM STEELS IN MALATE BUFFER AND VICTORIA PLUM SYRUP

Specimen	Corrodant	Hydrogen evolved during first day, ml	Steady rate, ml/day
Steel 1 (10 cm²)	Plum syrup *A*	0·65	0·25
,, ,,	Plum syrup *B*	0·15	0·15
,, ,,	Plum syrup *B* + 25 p.p.m. Sn++	0·0	0·11
,, ,,	Plum syrup *D*	1·4	0·22
Steel 2 (4 cm²)	Malate buffer (pH 3·0)	0·88	0·88
,, (10 cm²)	Plum syrup *B*	0·3	0·10
,, ,,	Plum syrup *C*	4·5	0·14
,, ,,	Plum syrup *C* + 25 p.p.m. Sn++	0·0	0·076
,, ,,	Plum syrup *D*	2·4	0·19

mercury manometer. One limb of this was made from a 1-ml pipette graduated in 0·01-ml divisions. The mercury was brought up to the barrel of the tap T_1 and the hydrogen, which had collected below the tap, was sucked into the graduated limb of the manometer. After levelling off, the volume of hydrogen was read and corrected to N.T.P. The hydrogen evolved was measured at regular intervals and plotted as a function of time. In the later experiments on the corrosion of steel–tin couples, hydrogen was used, instead of nitrogen, to de-aerate the corrodant, to eliminate any error in the relatively small volume of hydrogen evolved owing to its solubility in the corrodant. The hydrogen, from a cylinder, was passed over palladized asbestos to remove oxygen.

At the end of the corrosion period, the specimens were removed, washed with water, rinsed with acetone, dried, and re-weighed. Good equivalence was found between the volume of hydrogen evolved and the weight of iron dissolved. The triplicate experiments usually gave results agreeing to within $\pm 5\%$, and values of gas volumes and corrosion rates quoted are the means.

For studying the effect of coupling with tin on the corrosion rate of steel, couples were prepared in the following manner. Tin was electrodeposited on both sides of a steel strip from a proprietary bath and 8 cm × 0·8 cm specimens were cut from the coated strip. Both faces of the specimen were then lacquered so that only a 7·5 cm × 0·2 cm rectangular area remained uncoated in the centre of each face. After the edges of the specimen had been dipped into molten picein, the tin was stripped from the unlacquered areas by anodic polarization in N HCl at a current density of 3mA/cm². During the process the potential of the specimen was observed and, as soon as it rose to a value characteristic of the steel base, the specimen was removed. The steel thus exposed had a total area of 3 cm² and a perimeter of 30·8 cm, along which was a wall of tin of height equal to the thickness of the tin coating. A couple prepared from strip carrying a 2-μ thick coating of tin, for example, would have a steel/tin area ratio of about 500 : 1. The rate of hydrogen evolution from these couples

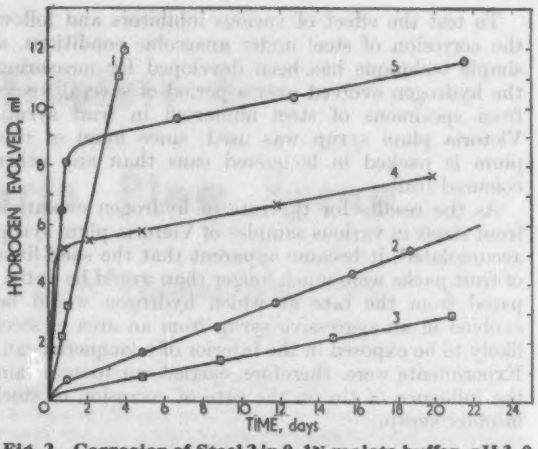


Fig. 2—Corrosion of Steel 2 in 0·1N malate buffer, pH 3·0 (curve 1), Victoria plum syrups *A*, *B*, and *C* (curves 2, 3, and 4), and air-saturated syrup *C* (curve 5)

was compared with that from a steel specimen of the same size and with the same exposed area of steel.

For studying the corrosion of steel in the presence of metallic tin, but not coupled to it, two combinations were used. In one, combination *A*, a 5 cm × 1 cm strip of blackplate was held between two similar strips of pure tinfoil and spaced 2 mm away from each by picein at the ends of the strips. Strips of Perspex were inserted temporarily between the steel and the tin while the picein was applied to the ends. The outer faces of the tin strips were lacquered so that the areas of steel and tin exposed were each 10 cm². In the other, combination *B*, rectangles of blackplate and tinfoil, each 2·5 cm × 0·8 cm, were cemented by picein at opposite ends of a strip of Perspex 13 cm × 0·8 cm. The shortest distance between the two metals was thus 8 cm. This unit was placed in the corrosion apparatus with the blackplate at the upper end. The blackplate for both arrangements was obtained by anodically stripping the tin and alloy layers from C20 hot-dipped tinplate. To serve as a control in experiments with combination *A*, another assembly was made up in which strips of Perspex were used instead of tin. In the blank for combination *B*, the tin rectangle was omitted.

RESULTS

Corrosion of Steel in Plum Syrup and in a Malate Buffer

Figure 2 shows the corrosion behaviour of Steel 2 in Victoria plum syrups *A*, *B*, and *C* compared with a 0·1 N malate buffer of pH 3·0. Malic acid is the principal acid of Victoria plums and this solution corresponds approximately in concentration and pH to the plum syrup. The corrosion rates for Steels 1 and 2 are shown in Table II. Steel 1 was used mainly in plum syrups *A* and *B*, and Steel II in plum syrup *C*, the two steels behaving similarly. In the plum syrups, after a few days the corrosion rates reach steady values which are maintained for 60 days. The steady corrosion rates in the various batches of

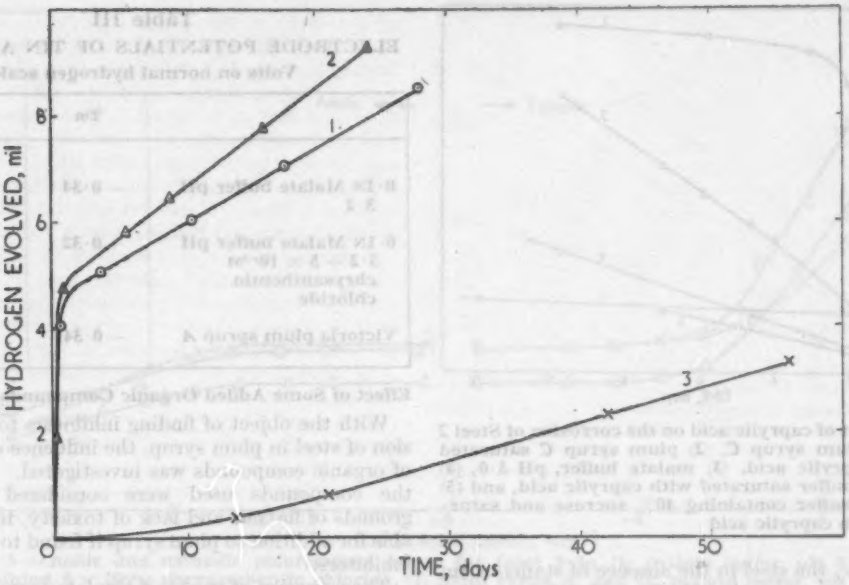


Fig. 3—Corrosion of Steel 2 in plum syrup C (curve 1), with 80 p.p.m. of stannic tin (curve 2), and with 25 p.p.m. of stannous tin (curve 3)

plum syrup differ, but are all considerably less than in the malate buffer. This indicates that the plum syrup contains inhibitors for the corrosion of steel.

A large variation also exists in the amounts of hydrogen evolved during the first day. In plum syrup *C*, more than twice as much hydrogen is evolved during the first day as in the malate buffer. In the corrosion of steel specimens 2·0 cm × 1·0 cm, approximately the same amount of hydrogen is evolved in the fast initial reaction as is obtained from the larger steel specimens of size 5·0 cm × 1·0 cm and the time before reaching the steady corrosion rate is longer with the smaller specimens. These observations show that the initial high rate of hydrogen evolution is due to the presence in the syrup of corrosion accelerators which are used up rather than to a change in the surface of the steel as corrosion proceeds. Although the steady corrosion rates of the various steels in a given syrup are similar, it will be seen from Table II that there is quite a wide variation in the initial rates. Thus the effectiveness of an accelerator appears to depend on the type of steel.

It seems that the accelerators are either unstable or oxidizable substances; for on keeping syrup *C* at room temperature, the volume of gas evolved in the accelerated reaction decreased, and with syrup *D*, which, as already mentioned, was prepared from the batch of plums used for *C* after they had been in cold storage for about 7 months, only 2·4 ml of hydrogen were evolved from a specimen of Steel 2 of 10 cm² area during the first day, compared with 5·2 ml for syrup *C*. Although the initial rate of corrosion in syrup *D* was less, the steady rate was higher, the values for syrups *C* and *D* being, respectively, 0·14 and 0·19 ml of hydrogen per day from 10 cm² of steel. This suggests that corrosion-inhibiting substances present in the plums are also destroyed on storage.

When nitrogen is bubbled through the plum syrup to remove oxygen, a foam is formed which is so stable that some of it escapes from the flask containing the plum syrup and is lost together with its surface active constituents. The corrosion of steel in plum syrup *C*, which had not had nitrogen bubbled through it and so had suffered no loss of surface active constituents, is shown by curve 5 in Fig. 2.

The amount of initial reaction is increased by about 50% whereas the steady corrosion rate is unaffected. This indicates that the accelerators are adsorbed at the gas/water interface and lost in frothing, whereas the inhibitors are not.

Effect of Tin Ions

Stannous tin was found to act as an inhibitor. Curve 3 in Fig. 3 illustrates the effect on the corrosion of Steel 2 of 25 p.p.m. stannous tin dissolved as citrate in anaerobic plum syrup *C*. The initial accelerated rate is completely eliminated and the steady corrosion rate is halved. Similar results were obtained in the other syrups except that in syrup *A* containing 25 p.p.m. stannous tin, inhibition was observed over the first few days but the corrosion rate gradually increased and, after about 30 days, it became faster than in the plain syrup. In this syrup, better inhibition was observed with 100 p.p.m. stannous tin and although the corrosion rate again tended to increase, after 60 days it was still only one-fifth the natural rate. Measurement of the change with time of the electrode potential of Steel 3 in anaerobic plum syrup *D*, with and without 25 p.p.m. stannous tin, revealed that, for the first day or so, both potentials became more negative until there was a maximum difference between them of

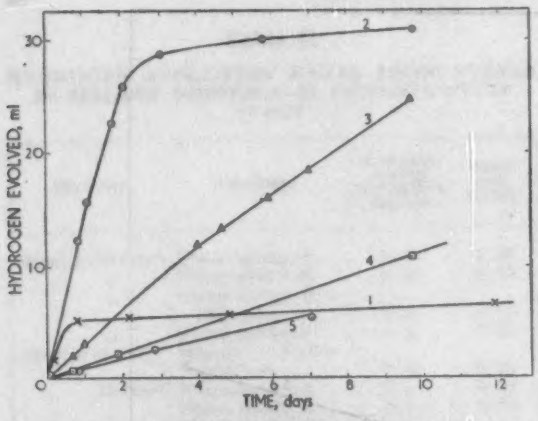


Fig. 4—Effect of caprylic acid on the corrosion of Steel 2 in (1) plum syrup *C*, (2) plum syrup *C* saturated with caprylic acid, (3) malate buffer, pH 3·0, (4) malate buffer saturated with caprylic acid, and (5) malate buffer containing 40% sucrose and saturated with caprylic acid

about 20 mV, the steel in the absence of stannous tin being the more negative. After this there was a drift in the positive direction and the potentials became equal after about 4 days.

Curve 2 in Fig. 3 shows the effect of stannic tin, obtained by dissolving stannous citrate in the plum syrup and saturating with oxygen to ensure oxidation to the stannic state, followed by de-aeration with nitrogen. In plum syrup *C*, 80 p.p.m. stannic tin had little effect on the initial accelerated rate, but increased the steady rate by about 30%. In syrup *B*, 10 p.p.m. stannic tin again increased the steady rate by about 30%. It was found that the presence of 25 p.p.m. of stannic tin shifted the potential of Steel 3 in anaerobic syrup *D* by about 60 mV in the positive direction. This shift occurred within a few hours of bringing the syrup into contact with the steel and was maintained throughout the observation period of 5 days.

In view of the difference in effect of stannous and stannic ions on the corrosion of steel in plum syrup, their behaviour was compared in 1% malic acid, pH 2·30. In this solution, potential measurements reveal that tin is initially cathodic to steel, but after about 30 min the tin becomes anodic to steel. It was found that an addition of 25 p.p.m. of stannous or stannic tin caused the same amount of inhibition of steel corrosion, the corrosion rate being reduced to a fifth.

Effect of Bismuth Ions

Addition of bismuth ions to the plum syrup would be expected to inhibit steel corrosion for two reasons:

(i) Since bismuth sulphide is insoluble, the sulphur from the steel should be precipitated, thus eliminating its acceleratory action[8]

(ii) Since bismuth is more electro-negative, it should deposit on the steel and so raise its hydrogen overpotential.

However, addition to plum syrup *C* of 25 p.p.m. bismuth citrate was found to have no effect on the initial corrosion rate, and it increased the steady rate.

Table III

ELECTRODE POTENTIALS OF TIN AND STEEL

Volts on normal hydrogen scale

	Tin	Steel
0·1N Malate buffer pH 3·2	− 0·34	− 0·39
0·1N Malate buffer pH 3·2 + 5 × 10^{-3}M chrysanthemin chloride	− 0·32	− 0·32
Victoria plum syrup *A*	− 0·34	− 0·31

Effect of Some Added Organic Compounds

With the object of finding inhibitors for the corrosion of steel in plum syrup, the influence of a number of organic compounds was investigated. In general, the compounds used were considered likely, on grounds of flavour and lack of toxicity, to be acceptable for addition to plum syrup if found to be effective inhibitors.

The corrosion of steel in a tinplate container always occurs in the presence of dissolved tin.[9] To reproduce these conditions, the corrosion experiments with added organic substances were done in the presence of 25 p.p.m. stannous tin. The following possible inhibitors were tried: caprylic acid, quercitin, coumarin, and sebacic acid, all in saturated solution; caproic acid, sodium gluconate, glutamic acid, all in 0·01N solution. Of these only caproic and caprylic acids had any effect on the corrosion rate, both acids halving the quantity of hydrogen evolved over 20 days in plum syrup *A*.

In acid solution many nitrogen compounds act as inhibitors for steel corrosion. β-naphthoquinoline is normally a good inhibitor, but, added to plum syrup in 0·01M solution, it increased the corrosion rate of steel about four times. The amino acid proline at a concentration of 0·01M had no effect on the corrosion.

Effect of Caprylic Acid

Curve 2 in Fig. 4 illustrates the effect of saturating Victoria plum syrup *C* with caprylic acid. Very rapid corrosion results, the rate being about six times faster than in the 0·1N malate buffer of pH 3·0. The rapid corrosion continues until the acid in the syrup has all reacted. In the presence of 25 p.p.m. stannous tin, the saturated solution of caprylic acid in plum syrup *C* shows some inhibition. The rate of corrosion is about 15% less than with the tin alone, so the effect is not so great as in plum syrup *A*. Curve 4 in Fig. 4 shows that in the 0·1N malate buffer, saturation with caprylic acid causes inhibition. When the malate buffer is made 40% in sucrose, corresponding to the syrup strength, the inhibition by caprylic acid is somewhat greater.

Potential measurements of steel corroding in plain syrup indicate that the transition from the accelerated rate to the steady rate is accompanied by a change in potential to a more positive value. When the steel is corroding at the steady rate, addition of caprylic

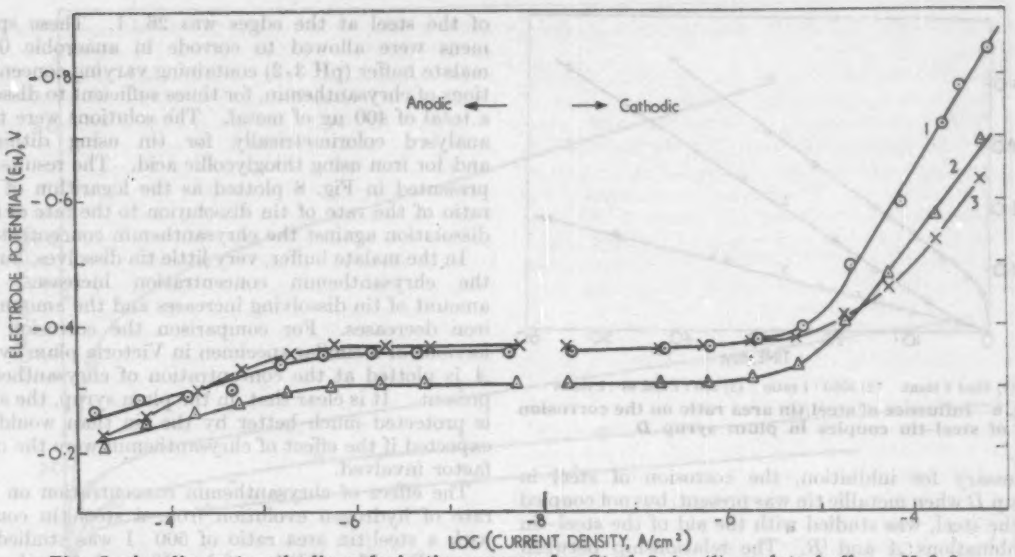


Fig. 5—Anodic and cathodic polarization curves for Steel 2 in (1) malate buffer, pH 3·2, containing 5×10^{-3}M chrysanthemin chloride, (2) plum syrup *A*, and (3) malate buffer, pH 3·2

acid increases the corrosion rate and makes the steel potential more negative. Thus caprylic acid functions by facilitating the anodic process.

Effect of Chrysanthemin

The principal colouring matter of Victoria plums is the anthocyanin chrysanthemin,[10] the concentration of which in the syrup can be readily determined from the absorption spectrum.[11] We have already shown that chrysanthemin can act as a depolarizer for the dissolution of tin.[1] The effect of chrysanthemin on the corrosion of steel and steel–tin couples has now been investigated.

Using the experimental technique previously described,[1] the anodic and cathodic polarization curves of steel have been determined in chrysanthemin solution and Victoria plum syrup. Curve 1 in Fig. 5 shows that the presence of 5×10^{-3}M chrysanthemin chloride in 0·1N malate buffer of pH 3·2 increases the slope of the plot of potential against the logarithm of the current density. This implies that chrysanthemin can act as an inhibitor of the process of hydrogen evolution. The anodic polarization curve is little affected by the presence of chrysanthemin. However, the static potential measurements given in Table III reveal that chrysanthemin displaces the steel potential to a more positive value. This means that chrysanthemin predominantly inhibits the anodic process. The inhibitive effect of chrysanthemin on steel corrosion has been confirmed in 0·1N malate buffer of pH 3·2 where $1·2 \times 10^{-3}$M chrysanthemin halved the corrosion. The colour of the chrysanthemin faded during the corrosion, so that some reduction was also occurring.

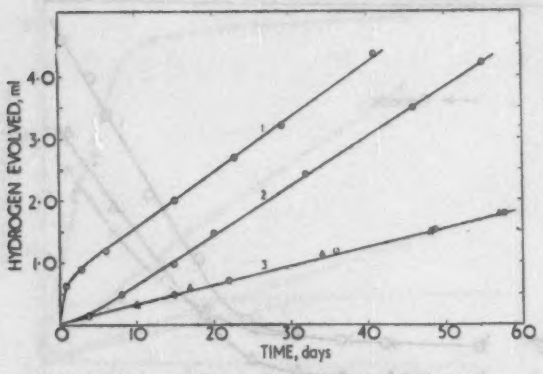
In plum syrup *C*, addition of 2×10^{-4}M chrysanthemin, which was about three times the original concentration of 8×10^{-5}M, had no appreciable effect on either the accelerated corrosion rate or the steady rate.

Effect of Metallic Tin

Although plum syrup *C* was found to be very aggressive in its initial attack on steel, storage tests revealed that the same plums packed in lacquered cans gave a shelf-life before swelling which was longer than average for Victoria plums.[11] This indicated that the initial rapid attack on the steel was completely absent in the can, as otherwise hydrogen swelling or perforation would have occurred in a very short time. In view of the ability of stannous tin to eliminate completely the initial rapid corrosion of steel (Fig. 3), experiments were carried out to determine the properties of steel–tin couples with a tin area very much smaller than the steel area, such as might be found in a lacquered can after the dissolution of tin exposed at damaged regions of the lacquer, e.g. along the side seam. It was considered that at the side seam, there might result, as an extreme case, a strip of steel up to 2 mm wide coupled in effect around its perimeter with the thickness of the tin coating, the rest of the tin coating of the can being covered by the lacquer. Accordingly couples of this type were prepared, as described above in the section on experimental technique, and their corrosion studied in plum syrup.

The effect of steel/tin area ratio on corrosion was investigated with couples prepared from Steel 3 strips bearing unflowbrightened electrodeposits of tin 0·28, 1·9, and 15 μ thick. These were equivalent to coating weights of about 4 oz, 20 oz, and 10 lb per basis box. The corresponding steel/tin area ratios were 3500, 500, and 64 to 1. Figure 6 shows that the rate of hydrogen evolution is syrup *D* from the couple with the largest steel/tin area ratio is only slightly less than that for the blank, whereas the rates for the other two couples are less than a third of it. Even with the largest ratio the initial rapid rate is eliminated.

To see whether coupling of the tin to the steel was



(1) Steel 3 blank (2) 3500 : 1 ratio (3) 500 : 1 and 64 : 1 ratios

Fig. 6—Influence of steel/tin area ratio on the corrosion of steel–tin couples in plum syrup *D*

necessary for inhibition, the corrosion of steel in syrup *D* when metallic tin was present, but not coupled to the steel, was studied with the aid of the steel–tin combinations *A* and *B*. The relationship between volume of hydrogen evolved and period of corrosion for both of these systems is shown in Fig. 7. With combination *A*, in which the tin was close to the steel, the initial rapid evolution of hydrogen exhibited by the blank is largely eliminated and the steady rate is reduced to about a third. With combination *B*, in which the tin was distant from the steel, the effect on the initial rate is less pronounced, the steady rate of hydrogen evolution being about half that for the blank.

Effect of Malic Acid Concentration on the Corrosion of the Steel–Tin Couple

Malic acid was added to syrup *D* at a concentration of about 3%, bringing the pH down to 2·3. When the 500 : 1 steel/tin area-ratio couple was allowed to corrode in this acidified syrup, the rate of hydrogen evolution was more than twice that in the plain syrup. It would not be anticipated from this result that, as Dickinson[11] has found, a long shelf-life of canned Victoria plums is associated with a high malic acid content.

Effect of Chrysanthemin on the Corrosion of the Steel–Tin Couple

The potentials given in Table III show that in 0·1N malate buffer (pH 3·2), steel is anodic to tin, whereas in Victoria plum syrup the situation is reversed. This accords with the work of Kohman and Sanborn[12] who found that fruit syrups contain substances which make steel cathodic to tin. With 5×10^{-3}M chrysanthemin added to the buffer, the potentials of steel and tin are about the same, so it appears that chrysanthemin is one of the fruit constituents which can influence the steel–tin couple, the effect being mainly on the steel, the potential of which is made 0·07 V more positive.

To invesitgate this further, the influence of chrysanthemin on the corrosion of steel–tin couples has been studied. Some of these experiments were done with strips of tinplate 2·5 cm × 1·0 cm × 0·027 cm, so that the ratio of the area of tin on the faces to that of the steel at the edges was 26 : 1. These specimens were allowed to corrode in anaerobic 0·1N malate buffer (pH 3·2) containing varying concentrations of chrysanthemin, for times sufficient to dissolve a total of 400 μg of metal. The solutions were then analysed colorimetrically for tin using dithiol,[13] and for iron using thioglycollic acid. The results are presented in Fig. 8 plotted as the logarithm of the ratio of the rate of tin dissolution to the rate of iron dissolution against the chrysanthemin concentration.

In the malate buffer, very little tin dissolves, but as the chrysanthemin concentration increases, the amount of tin dissolving increases and the amount of iron decreases. For comparison the corrosion behaviour of a similar specimen in Victoria plum syrup *A* is plotted at the concentration of chrysanthemin present. It is clear that, in the plum syrup, the steel is protected much better by the tin than would be expected if the effect of chrysanthemin were the only factor involved.

The effect of chrysanthemin concentration on the rate of hydrogen evolution from a steel–tin couple with a steel/tin area ratio of 500 : 1 was studied in syrup *D*. The addition of 2×10^{-4}M chrysanthemin to the syrup, which was itself devoid of chrysanthemin, slightly increased the rate of hydrogen evolution.

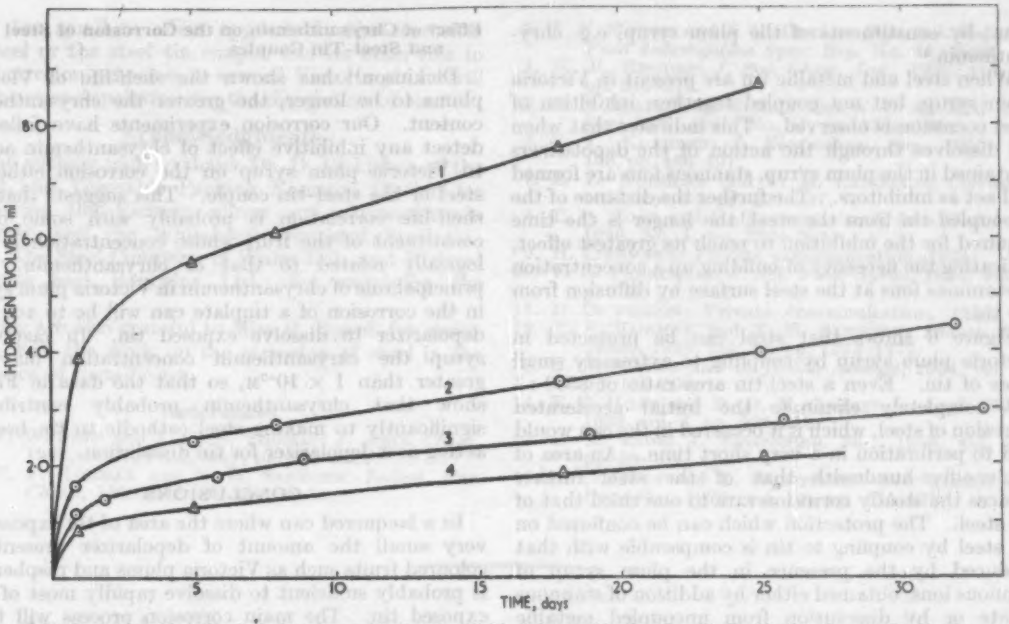
DISCUSSION

Corrosion of Steel in Victoria Plum Syrup

The corrosion of steels in Victoria plum syrup is quite different from that in malic acid solution of the same pH and concentration since the plum syrup contains both inhibitors and accelerators of the corrosion. All four samples of plum syrup tested contained very effective inhibitors of steel corrosion, the steady corrosion rates being reduced by as much as ten to twenty times. These inhibitors act by being adsorbed on the steel,[14,15] the reaction sites where adsorption forces are powerful being occupied by inhibitor molecules, leaving empty only the sites where adsorption forces are weak. Therefore to inhibit completely the corrosion, any substance added to the plum syrup must block the vacant weakly-adsorptive reaction sites. The inability to do this probably accounts for the ineffectiveness of the majority of possible inhibitors added to plum syrup.

The nature of these inhibitors present in Victoria plum syrup is at present unknown but their identification would be of great interest. The steady corrosion rate in plum syrup was increased by the addition of stannic tin, bismuth, and β-napthoquinoline. These substances may react with the natural inhibitors in the syrup making them inactive. All three substances are positively charged ions, which suggests that the inhibitors are negatively charged ions or acidic in nature. The comparatively strong adsorption of the natural inhibitors on steel suggests that by treating plum syrup with iron powder of large area, the inhibitors would be adsorbed on the iron, from which they might be desorbed and identified.

Victoria plum syrup may also contain accelerators



(1) Blank of stripped hot-dipped tinplate for combination *A* (2) Blank for combination *B* (3) Combination *B* (4) Combination *A*

Fig. 7—Influence of metallic tin on the corrosion of steel in plum syrup *D*

for the corrosion of steel, which can even increase the corrosion rate compared to that in an equivalent solution of malic acid. The decrease in the amount of initial accelerated reaction by frothing the syrup indicates that the accelerators are surface-active. Thus foam fractionation of the syrup might provide a method for the isolation and identification of the accelerators. In this connection the similar accelerator action of caprylic acid in plum syrup (Fig. 4) may be significant, since straight-chain fatty acids are known to occur in fruits, e.g. hexoic acid has been reported in raspberries.[16] However, the inhibitory action of caprylic acid in malic acid suggests that the former must act in conjunction with some other constituent of the plum syrup to accelerate corrosion.

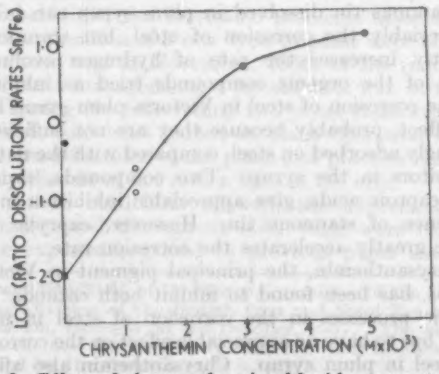


Fig. 8—Effect of chrysanthemin chloride concentration on the corrosion of a steel–tin couple with a 26 : 1 tin/steel area ratio in a pH 3·2 malate buffer. The black circle represents the corrosion in plum syrup *A*

Effect of Tin

The experimental results reveal that whereas in 1% malic acid the corrosion of steel is inhibited by the presence of either stannous or stannic tin, in Victoria plum syrup stannous tin inhibits and stannic tin increases the corrosion rate. The similar inhibitive behaviour of stannous and stannic tin in malic acid can probably be explained as follows. We have found that in a 0·1N malate buffer (pH 3·0) the redox potential of the stannous–stannic system as given by a platinum electrode in the mixed solution is + 0·09 V. Since the standard potential for the reaction $Fe^{++} + 2e \rightarrow Fe$ is − 0·44 V, it is clear that, even allowing for the overpotential in the dissolution of iron, metallic iron should reduce stannic tin to stannous. Thus in whatever form the tin is present originally it will inhibit in the stannous state. In plum syrup, the different behaviour of stannous and stannic tin suggests that the redox potential is not sufficiently more positive than the steel electrode potential for reduction of stannic ions to occur.

In agreement with previous work,[6, 8] stannous tin was found to act as an anodic inhibitor, the corroding potential of steel being displaced in the positive direction in both malic acid and Victoria plum syrup. In plum syrup, the acceleration of the corrosion of steel by stannic tin is accompanied by a shift of the corroding potential in the positive direction. This is presumably caused by a decrease in slope of the curve for cathodic self-polarization, which might be due to the inactivation of cathodic inhibitors as a result of complex formation with stannic ions. The accelerator action of bismuth in plum syrup can probably be explained similarly. The diminishing effect of hydrogen evolution of stannous tin with time in syrup *A* may be due to the slow oxidation to the stannic

form, by constituents of the plum syrup, e.g. chrysanthemin.[1]

When steel and metallic tin are present in Victoria plum syrup, but not coupled together, inhibition of steel corrosion is observed. This indicates that when tin dissolves through the action of the depolarizers contained in the plum syrup, stannous ions are formed and act as inhibitors. The further the distance of the uncoupled tin from the steel, the longer is the time required for the inhibition to reach its greatest effect, indicating the necessity of building up a concentration of stannous ions at the steel surface by diffusion from the tin.

Figure 6 shows that steel can be protected in Victoria plum syrup by coupling to extremely small areas of tin. Even a steel/tin area ratio of 3500 : 1 will completely eliminate the initial accelerated corrosion of steel, which if it occurred in the can would lead to perforation in a very short time. An area of tin one-five-hundredth that of the steel further reduces the steady corrosion rate to one third that of the steel. The protection which can be conferred on the steel by coupling to tin is comparable with that produced by the presence in the plum syrup of stannous ions, obtained either by addition of stannous citrate or by dissolution from uncoupled metallic tin. This indicates that the steel–tin couple functions through the inhibitive action of stannous ions dissolved from the tin by anodic solution, since tin is anodic to steel in the plum syrup, and also by the action of depolarizers present in the syrup, as discussed above. As a consequence of the geometry of the steel–tin couples used, stannous ions are produced in close proximity to the steel by dissolution of the surrounding tin, thus accounting for the effect of such small areas of tin. In Victoria plum syrup, our observed corrosion rates do not show any evidence of an enhanced inhibitive action of tin, when coupled to steel. This shows that the 'anodic coupling shift' mechanism of the steel–tin couple, described by Koehler and Canonico,[7] is of secondary significance.

Since the rates of evolution of hydrogen for the 500 : 1 and 64 : 1 couples are almost equal and considerably lower than that for the 3500 : 1 couple, a couple with a steel/tin ratio between 3500 and 500 to 1 should be able to maintain a concentration of stannous ions in the vicinity of the steel sufficient to achieve the limiting amount of inhibition. Addition of a stannous salt to plum syrup, in which a couple with a steel/tin area ratio equal to or less than the optimum value was corroding, would presumably not affect the rate of hydrogen evolution. This was found to be so for the 64 : 1 couple in syrup *D* containing 25 p.p.m. of stannous tin.

It is difficult to relate these results directly to the corrosion process in a lacquered can of Victoria plums, because too much depends on the extent of any damage to the lacquer. If there were only small discontinuities in the lacquer, the couples produced might have steel/tin area ratios of 500 : 1 or less, even with C4 tinplate. On the other hand, with C20 tinplate, long cracks or slits in the lacquer such as might occur along the seams of a can could be 2 mm wide without causing the 500 : 1 ratio to be exceeded.

Effect of Chrysanthemin on the Corrosion of Steel and Steel–Tin Couples

Dickinson[11] has shown the shelf-life of Victoria plums to be longer, the greater the chrysanthemin content. Our corrosion experiments have failed to detect any inhibitive effect of chrysanthemin added to Victoria plum syrup on the corrosion either of steel or the steel–tin couple. This suggests that the shelf-life correlation is probably with some other constituent of the fruit whose concentration is biologically related to that of chrysanthemin. The principal role of chrysanthemin in Victoria plum syrup in the corrosion of a tinplate can will be to act as a depolarizer to dissolve exposed tin. In raspberry syrup the chrysanthemin concentration may be greater than 1×10^{-3}M, so that the data in Fig. 8 show that chrysanthemin probably contributes significantly to making steel cathodic to tin besides acting as a depolarizer for tin dissolution.

CONCLUSIONS

In a lacquered can where the area of tin exposed is very small the amount of depolarizer present in coloured fruits such as Victoria plums and raspberries is probably sufficient to dissolve rapidly most of the exposed tin. The main corrosion process will then consist of the steel base dissolving in fruit syrup containing some tin, at a rate which may be markedly affected by contact of the perimeter of the exposed steel with the small area of tin (and iron–tin alloy) formed by the edge of the tin layer. With such a steel–tin couple, an area of tin only one-five-hundredth that of the steel may reduce its rate of corrosion in plum syrup to a third.

The corrosion behaviour of steel in Victoria plum syrup indicates that the syrup contains, in varying amounts, both accelerators and inhibitors of the corrosion. The accelerators affect the initial corrosion but appear to be quickly used up since the corrosion rate rapidly decreases to a steady value, which is maintained over a period of months. The steady corrosion rates of steel in plum syrup are ten to twenty times less than in a malic acid solution of the same strength and pH, indicating that the natural inhibitors are very effective.

Stannous tin dissolved in plum syrup can inhibit appreciably the corrosion of steel, but stannic tin slightly increases the rate of hydrogen evolution. Most of the organic compounds tried as inhibitors of the corrosion of steel in Victoria plum syrup have no effect, probably because they are not sufficiently strongly adsorbed on steel, compared with the natural inhibitors in the syrup. Two compounds, caprylic and caproic acids, give appreciable inhibition in the presence of stannous tin. However, caprylic acid alone greatly accelerates the corrosion rate.

Chrysanthemin, the principal pigment in Victoria plums, has been found to inhibit both cathodic and anodic processes in the corrosion of steel in malic acid, but to have no appreciable effect on the corrosion of steel in plum syrup. Chrysanthemin also affects the corrosion of a steel–tin couple in malic acid, mainly by making the electrode potential of steel more positive. However, the concentration of chrysanthemin usually present in Victoria plums is prob-

ably too small to affect appreciably the corrosion of steel or the steel–tin couple, and its main role in the corrosion processes in canned Victoria plums will be to act as depolarizer for the dissolution of tin.

Acknowledgments

The authors wish to thank Dr. D. Dickinson of the Fruit and Vegetable Packing Research Station for supplying the Victoria plums and chrysanthemin chloride, and the Whitehead Iron and Steel Co., Ltd., The Steel Company of Wales Ltd., and Richard Thomas and Baldwins Ltd., for supplying the steel.

They are also grateful to Miss M. Bowen for assistance with the work on the corrosion of steel in the presence of metallic tin.

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Sinter-plant Assessment Trials

AT JOHN SUMMERS AND SONS, LTD., SHOTTON

By H. Bates, G. C. Carter, and D. F. Ball

SYNOPSIS

Continuing the policy of assessing the performance of sinter plants, trials have been carried out at the Shotton works of John Summers and Sons, Ltd. The leakage of air between the strand and the fan was measured and was found to be similar to that obtained during other B.I.S.R.A. assessment trials, amounting to about half of the total air at the fan. The air requirement, corrected for this leakage, was found to be constant at 25,000 ft³ per ton of raw mix. Reference is made to the performance of the sinter cooler. 1486

TWO SEPARATE full-scale sinter-plant assessment trials have been carried out at the Shotton sinter plant and the results incorporated in a joint report. The first assessment of plant performance was made in December, 1954, shortly after the plant was brought into commission.

At that time, the inevitable problems associated with the operation of a new type of plant were being encountered and in November, 1956, at the request of the plant management, a second trial was carried out. During the intervening two years considerable experience had been gained in plant operation and certain modifications to the plant and practice made, notably the use of hot return fines in the mix.

As far as conditions allowed, the experimental techniques used throughout both trials were based on the experience gained in previous plant assessments.[1–3] The first trial lasted three weeks—two consecutive weeks in December, 1954, and one week in February, 1955—and the second trial lasted nine consecutive working days in November, 1956. When possible, assessments were made over 2 or 3 h; the variables measured were fan air flow and temperature, fan and strand suctions, and the input of raw material. During most of the tests the plant was operated normally, such variables as mix composition and strand speed being controlled by the operator. The leakage of air into the plant and the pressure drop between the strand and the fan were measured and a check on the fan performance was obtained. Throughout the trials the team enjoyed the fullest co-operation from the sinter plant management and operators, and also the services of the company's instrument section, laboratory, and fitting shop.

Paper IM/S/23/57 of the Sinter Committee of the Ironmaking Division of the British Iron and Steel Research Association, received on 4th October, 1957. The views expressed are the authors', and are not necessarily endorsed by the Committee as a body.

The authors were with the Association's Ironmaking Division when the work described in the paper was carried out; Mr. Bates has since joined Huntington, Heberlein and Co., Ltd., and Mr. Carter has joined John Summers and Sons, Ltd.

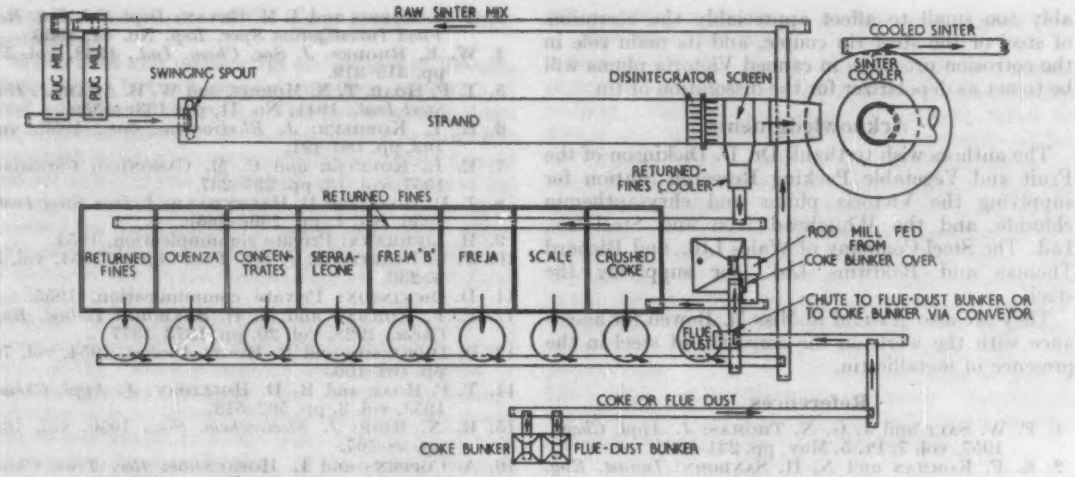


Fig. 1—Diagrammatic arrangement of the Shotton sinter plant

DESCRIPTION OF THE PLANT

The following is a description of the plant at the time of the first assessment trial; any modifications or additions made before the second trial are described later.

Sinter Machine

The sinter plant at John Summers, Shotton, is a single continuous strand built by Head Wrightson and Co., Ltd.; it came into commission in May, 1954. Figure 1 shows a diagrammatic arrangement of the plant layout. The strand is 6 ft wide with an effective length of 120 ft divided into 20 equal windboxes, giving a total grate area of 720 ft². The strand is made up of 143 pallets, 6 ft wide and 2 ft long, fitted with drop bar seals. The maximum bed height which can be obtained is 14 in. and the strand speed is controllable between 3 and 12 ft/min. The windlegs are connected to a common waste-gas main which connects to twin cyclone dustcatchers in parallel and thence to the fan via twin mains fitted with Venturis for air-flow measurement. The fan is of the double box-inlet, constant-speed, vane-controlled type with a radial bladed impeller and is rated at 200,000 ft³/min at 27 in. w.g. suction and 120° C. The fan is directly coupled to a 750 rev/min motor and absorbs 1450 b.h.p. at the fan shaft at the above rating.

At the discharge end of the strand the sinter cake passes via a claw-type disintegrator over a Schenck vibrating screen and out of the building down a chute into a forced-draught rotary cooler. The cooler shown diagrammatically in Fig. 2 is essentially a large feeder table carrying the sinter in a V-shaped annulus. Air is blown through downward-facing louvres in the inner wall and passes up through the bed of hot sinter to atmosphere. The air supply to the cooler is from four independent fans connected in parallel, each rated at 50,000 ft³/min at 7 in. static pressure, and it is the usual practice to work with only three fans operating. The sinter is ploughed off the bottom and is transported to the blast-furnaces by belt conveyor.

Raw Materials

The ore fines, which are delivered to the covered stockbay by a conveyor system from the screen house, are the undersize from a double-decked screen, the upper screen being 1 in. square mesh and the lower $\frac{1}{2}$ in. × 3 in. The material arrives at the stockbay and is tripped from the conveyor belt into the appropriate storage bay, from which it is transferred by overhead crane to the feed bunkers. Coke and flue dust enter the plant by a separate system. The coke which arrives from the coke ovens as $-\frac{3}{8}$ in. is crushed in a rod mill to a nominal $-\frac{1}{8}$ in.

Before the sinter cooler, return fines are extracted by hot screening on a Schenck vibrating screen, the undersize, usually $-\frac{1}{2}$ in., falling into a hopper from which it is taken by a vibro conveyor to a pug mill. Here water is added and the cooled return fines pass up a long conveyor belt to the return-fines bunker ready to be charged into the feeder table hopper.

Mixing and Feeding

There are nine feeder tables in line feeding on to a single gathering conveyor belt. The speed of the feeder tables can only be controlled collectively, and individual feed rates are controlled by manually operating an adjustable door or plough on the table concerned in conjunction with tray weighings on the gathering belt. From the main gathering belt the feed passes via a cross belt to the main rising conveyor belt and into one of two pug mixers. Here the final mixing is carried out and a metered quantity of water added as required; the resulting mix is fed by a further belt conveyor to a swinging spout feeder.

The swinging spout discharges into an open hopper with an adjustable back plate, which deflects the feed against a vertical plate running the full width of the strand. This plate has a short inclined section (about 6 in.) immediately above the bed and acts as a cut-off plate, giving a partially segregated feed to the strand. This arrangement was originally designed for use with a fluffing device which was abandoned after initial trials. The swinging spout is provided with facilities for adjusting its amplitude so as to maintain

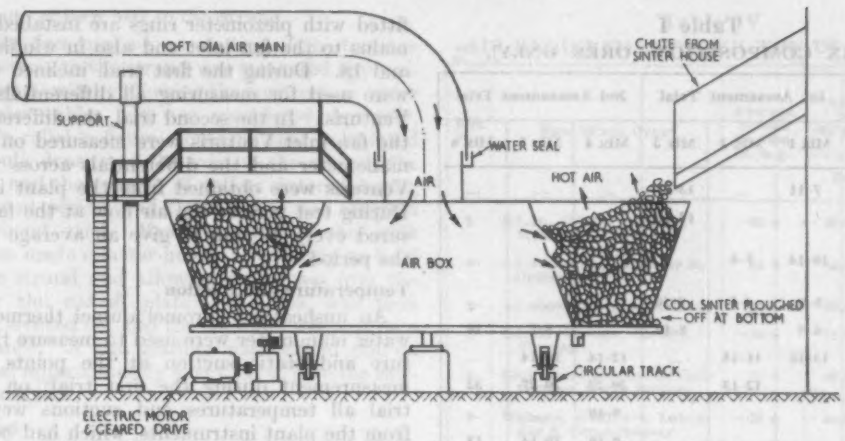


Fig. 2—Diagrammatic arrangement of circular forced-convection sinter cooler

the feed line as nearly horizontal as possible at the cut-off plate. An ignition hood which normally burns a 70 : 30 mixture of blast-furnace and coke-oven gas covers the first windbox. During the second assessment trial, however, only coke-oven gas was being burnt, and the average total heat input used for ignition was 2700 B.t.u./ft² at an intensity of 3300 B.t.u./ft²/min.

Plant Controls

All control switches for stopping and starting the strand, conveyor belts, feeder tables, etc. are situated in a control cabin on the strand floor, together with all the plant instruments, which are grouped together on a panel behind the control switches. The manual and automatic control levers for operating the fan vanes are placed at a convenient height on the instrument panel.

Plant Instrumentation

(1) Suctions at No. 19 windleg and the even-numbered windlegs, with the exception of No. 4, and at a point between the two cyclone dustcatchers and the fan, are indicated on vertical edgewise gauges and recorded on 24-hour circular charts, three suctions being recorded on each chart.
(2) Temperature indicators are installed in the position of suction measurement. During the second assessment trial a multi-point recorder was used to record the temperatures in the last three windlegs.
(3) Strand speed is indicated and recorded in feet and inches per minute.
(4) Coke-oven and blast-furnace gas flows to the ignition hood are indicated and recorded and gas pressures indicated.
(5) The sinter-plant fan power-consumption in kilowatts is indicated.
(6) The quantity of water added in the final mixer is indicated in gallons per hour.
(7) In addition to the above instruments, a belt weigher is installed to record the blast-furnace sinter output from the cooler. A repeater is incorporated in the control panel of the control cabin.

MODIFICATIONS CARRIED OUT BETWEEN FEBRUARY, 1955, AND NOVEMBER, 1956

Sinter Machine

The principal modification to the plant and process is the use of hot return fines in the raw mix. The return fines are screened out at $-\frac{1}{2}$ in. on a Schenck vibrating screen as before and fall into a hopper, with feeder table attached, capable of holding approximately a ¼-h supply. A small amount of water is sprayed continuously into the hopper, principally to alleviate the dust problem. From the feeder table the return fines are fed on to the raw mix on the cross belt immediately before the main uprising conveyor belt to the mixers (*see* Fig. 1). An individual speed control for the table is incorporated in the control panel on the strand floor.

Any excess of return fines which cannot be handled by the hot return-fines feeder table overflows from the hopper on to a vibro conveyor and is returned via the pug mill to the cold return-fines bunker as before.

Raw Materials

During the first assessment trial the ore fines were screened on a double-decked screen, the upper of which was 1 in. square and the lower ½ in. × 3 in., giving a nominal mix size of $-\frac{1}{2}$ in. Recently the size of the lower screen was changed to ⅝ in. × 2 in., giving a nominal ore-fine size of $-\frac{5}{8}$ in. during the second trial.

Plant Instrumentation

Additional instruments have now been installed to indicate and record the air flow through the main fan Venturis and indicate the differential in windlegs 2, 8, 13, and 18, which are fitted with Venturis. The air flow in cubic feet per minute at 60° F and 30 in. Hg is obtained from the instrument reading by applying a density correction, dependent mainly on the temperature of the air at the measuring point.

TRIAL CONDITIONS AND MEASUREMENTS

Both assessment trials were made under normal operating conditions, the mix composition used

Table I

BASIC MIX COMPOSITION (ORES ONLY), %

Ore	1st Assessment Trial			2nd Assessment Trial		
	Mix 1	Mix 2	Mix 3	Mix 4	Mix 5	Mix 6
Quenza	7–11	...	13–17	...	...	...
Kiruna	...	...	13–16	...	...	...
Sierra Leone Fines	10–14	7–8	...	...	...	...
Sierra Leone Conc.	5–6	4–5	9–10	...	...	...
Wabana	6–9	...	8–12	...	5–7	10
Gellivare	13–15	11–15	...	12–14	10–14	...
Labrador *B*	...	12–13	...	20–22	20–27	32
Coto Wagner	...	...	...	9–10	...	...
Cerro Bolivar	...	...	...	9–10	10–14	13

depending on the ores available. Measurements of the following variables were made:

(1) Total volume of air at the fan
(2) Air temperature and suction at the fan inlet
(3) Raw-mix feed rate and composition
(4) Strand speed and suction
(5) Windleg temperatures (where possible)
(6) Size and carbon segregation on the strand
(7) Percentage of CO_2 in the waste gas at the fan.

Measurements were made with the plant operating on the basic mix compositions shown in Table I, the balance to 100% being return fines, etc.

EXPERIMENTAL PROCEDURE

Air-flow Measurement

Excellent provision has been made in the Shotton sinter plant for air-flow measurements. Venturis fitted with piezometer rings are installed in the two mains to the fan inlet and also in windlegs 2, 8, 13, and 18. During the first trial, inclined manometers were used for measuring all differentials across the Venturis. In the second trial, the differentials across the fan inlet Venturis were measured on an inclined manometer and the differentials across the windleg Venturis were obtained from the plant instruments. During test periods the air flow at the fan was measured every 10 min to give an average air flow for the period.

Temperature and Suction

An unsheathed chromel/alumel thermocouple and water manometer were used to measure the temperature and static suction at the points of air-flow measurement during the first trial; on the second trial all temperatures and suctions were obtained from the plant instruments, which had been checked before the trial.

Mix Composition

Half-hourly readings of the raw-feed rate from each feeder table were obtained by placing a tray on the gathering belt and allowing it to pass under the feeder table concerned. On the second trial it was found impossible to carry out tray measurements on the hot return-fines feeder table owing to the presence of a considerable amount of dust and steam. The weight of hot return fines in the mix was therefore obtained by the difference between the total feed to the strand and the feed on the main gathering belt in the feeder bay. From the individual feed rates the percentage of each constituent in the mix was calculated on a 'dry mix' basis. A sample of each raw material was collected and analysed for size grading during each assessment of the second trial.

Table II—SUMMARIZED DATA ON SHOTTON SINTER-PLANT TRIAL, 1954–1955

Date (1954–1955)	7.12	7.12	8.12	13.12	15.12	15.12	15.12	31.1	1.2	1.2	2.2	2.2	2.2
Time	2.45–4.30 p.m.	6.30–7.30 p.m.	a.m.	3.15–4.15 p.m.	9.30–11.00 a.m.	11.00 12.30 a.m.	2.20–3.20 p.m.	5.30–7.00 p.m.	11.40–12.20 a.m.	3.00–4.00 p.m.	11.00–12.00 a.m.	2.00–4.00 p.m.	5.30–7.30 p.m.
Bed height, in.	12	12	12	12	12	12	12	10	10	10	12	12	10
Strand speed, in./min	60	52	66	83	85	83	85	106	99	96	78	82	102
Raw mix input, tons/h	102	88	114	140	145	141	146	148	137	132	131	136	148
Suction at windlegs, in. w.g.	39·2	34·1	28·4	27·0	24·0	26·0	26·2	25·2	28·0	25·0	28·2	27·2	25·8
Number of windboxes in use	20	20	20	20	20	20	20	20	20	20	20	20	20
Quenza in mix, %	8·4	11·2	6·9	...	...	...	...	16·6	16·3	17·2	13·8	14·4	13·1
Kiruna in mix, %	...	...	...	...	...	...	...	15·6	13·1	14·7	13·8	13·7	14·7
Sierra Leone fines in mix, %	10·6	11·5	9·7	14·2	7·8	8·3	7·4	...	...	...	...	...	...
Sierra Leone conc. in mix, %	5·4	4·8	6·2	5·3	4·8	4·6	4·9	10·0	9·7	8·9	9·0	9·4	9·8
Wabana in mix, %	8·5	9·3	6·7	6·0	...	...	...	8·7	8·0	8·6	10·7	9·4	11·9
Gellivare in mix, %	13·9	15·4	13·5	14·3	14·7	11·6	11·2	...	...	...	...	...	...
Labrador *B* in mix, %	...	...	...	...	12·2	12·5	12·9	...	...	...	...	...	...
Mill scale in mix, %	4·4	4·6	5·8	3·6	3·8	4·8	...	2·9	3·5	3·2	4·5	4·1	3·5
Return fines in mix, %	37·5	28·3	40·4	40·1	43·0	44·5	50·3	36·7	37·3	35·7	36·7	35·5	35·0
Fine dust in mix, %	7·5	9·6	7·2	5·5	5·8	5·5	5·3	6·5	9·0	8·1	8·6	8·4	8·8
Coke in mix, %	3·8	5·3	3·6	3·0	2·9	3·1	2·7	3·0	3·1	3·6	2·9	3·1	3·2
Basic slag in mix, %	...	...	...	...	...	5·1	5·3	...	...	...	...	...	...
Fan inlet temp., °C	80	55	76	103	134	108	96	106	75	117	90	93	100
Fan inlet suction, in. w.g.	34·6	37·9	33·2	31·3	28·4	30·8	31·7	30·5	33·1	29·6	32·1	31·8	30·8
Total air flow at fan, 10^3 ft³/min (S.T.P.)	101·7	100·0	106·2	116·5	112·6	116·5	120·0	119·0	121·0	110·0	117·4	122·0	118·0
Air flow through sinter bed, 10^3 ft³/min (S.T.P.)	39·7	34·0	46·2	55·3	57·5	59·0	62·0	62·0	61·0	54·0	57·4	63·0	61·0
Fan air per ton raw mix, 10^3 ft³ (S.T.P.)	59·8	68·1	56·0	50·0	46·7	49·5	49·3	48·2	53·0	50·0	53·8	53·8	47·8
Bed air per ton raw mix, 10^3 ft³ (S.T.P.)	23·4	23·2	24·3	24·6	23·8	25·1	25·4	25·2	26·7	24·6	26·2	27·8	24·7
Apparent permeability, B.P.U.	74·8	69·6	80·0	91·0	93·3	91·9	93·0	84·6	83·1	79·5	90·4	94·4	83·6
Average bed permeability, B.P.U.	31·7	25·2	38·2	49·1	52·7	51·5	53·8	49·4	45·8	43·3	47·7	53·5	48·0
Time on strand, min	24	28	22	17	17	17	17	13·5	14·5	15	18·5	17·5	14

Tonnage Input of Raw Mix to the Strand

During the first trial a spot reading of the tonnage input of raw mix to the strand was measured approximately every 20 min by allowing the tray to pass under all the feeder tables. It was considered, however, that a more reliable figure would be that calculated from the bulk density of the mix on the strand, the bed height, and the number of pallets sintered during the assessment period, and this method was adopted for the second trial. Measurements of the bulk density were made quarter-hourly by placing an $\frac{1}{8}$-ft^3 box on the strand and allowing it to pass into the feed below the cut-off plate. The box was then drawn out, levelled off, and the contents weighed on a spring balance. A size grading was carried out on this material approximately every $\frac{1}{2}$ h to give the raw-feed size analysis.

Strand Speed

Although the strand speed was indicated and recorded in feet and inches per minute, the average strand speed for each assessment period was calculated from the number of pallets sintered during the assessment.

Segregation of the Raw Feed on the Strand

A specially constructed multi-shovel was used to take samples simultaneously at six vertical levels in the bed from a position in front of the cut-off plate. The samples were then sieved to give the size fractions and selected samples were analysed for carbon content.

Percentage CO_2 in the Waste Gases at the Fan

Carbon dioxide measurements at the fan were obtained during the first trial by a thermal-conductivity continuous recorder which was checked periodically against an Orsat apparatus. Trouble was experienced, however, because the extraction pump was not sufficiently robust for continuous operation. Results obtained over several periods of approximately 0 h continuous operation showed that the percentage of CO_2 at the fan inlet was in the region of 2·5–3·5.

Moisture Content

The varying initial moisture content of the raw materials, particularly the return fines, resulted in rather wide fluctuations in the final mix-moisture content, a special series of determinations carried out

Table IV

AIR REQUIREMENTS PER TON OF RAW MIX

Mix No.	Raw Mixed Ores*	Average Strand Suction, in. w.g.	Average Air per ton of Raw Mix, ft³ (60° F and 30 in. Hg)	
			Fan	Bed
1	S.L.F., S.L.C., Ouenza, Wabana, Gellivare	30·0	58,500	23,900
2	S.L.F., S.L.C., Labrador *B*, Gellivare	24·0	46,700	23,800
2	As above + 5% basic slag	26·1	49,400	25,200
3	S.L.C., Ouenza, Kiruna, Wabana	26·6	51,500	25,800
4	Gellivare, Labrador *B*, Coto Wagner, Cerro Bolivar	21·4	48,800	26,600
5	Wabana, Gellivare, Labrador *B*, Cerro Bolivar	20·6	46,000	25,000
5	As above + 9% flue dust	25·4	46,700	22,700
6	Wabana, Labrador *B*, Cerro Bolivar	20·8	46,300	25,700
	Average for all assessments			25,000

* S.L.C. = Sierra Leone concentrates; S.L.F. = Sierra Leone fines

Table III

SUMMARIZED DATA ON SHOTTON SINTER-PLANT TRIAL, 1956

Bed height 12 in. throughout trial—20 windboxes in use

Date (1956)	20.11	20.11	22.11	22.11	22.11	23.11	23.11	23.11	24.11	25.11	26.11	26.11
Time	9.45–12.15 a.m.	2.00–4.00 p.m.	3.20–4.20 p.m.	4.20–5.00 p.m.	5.00–6.00 p.m.	10.00–11.30 a.m.	1.20–2.30 p.m.	2.30–5.00 p.m.	11.30–1.00 p.m.	10.20–12.30 a.m.	10.20–11.30 a.m.	3.00–5.00 p.m.
Strand speed, in./min	93·5	88·4	90·5	92·0	98·0	96·0	92·0	98·2	95·4	91·1	82·1	90·2
Bulk density of raw mix, lb/ft³	122	126	123	122	120	118	121	122	120	121	124	123
Raw mix input, tons/h	153	149	149	150	157	152	149	160	153	148	137	148
% Raw mix $-\frac{1}{4}$ in.	68	65	69	66	64	67	71	73	60	71	67	68
Suction at windlegs, in. w.g.	20·5	22·2	21·5	18·0	19·5	18·1	22·5	21·4	20·8	25·4	23·4	21·3
Hottest windbox number (indicated)	18	19	19	18	19	18	19	19	19	19	19	19
Temperature in hottest windbox, °C	260	244	369	417	384	331	300	337	322	237	243	310
Temperature in windbox 20, °C	230	230	347	351	348	282	282	316	291	217	212	280
Gellivar, in mix, %	12·3	14·5	11·2	11·1	12·8	9·3	13·9	12·7	...	12·7	13·4	12·3
Coto Wagner in mix, %	9·5	9·6	...	...	...	...	...	...	...	...	...	...
Labrador *B* in mix, %	21·2	22·1	20·0	19·8	23·2	19·7	27·5	25·8	31·8	21·3	23·6	23·2
Cerro Bolivar in mix, %	9·8	10·0	11·4	11·3	13·1	9·7	14·5	13·4	13·0	11·3	13·4	12·2
Wabana in mix, %	...	...	6·5	6·5	7·5	5·1	7·4	6·4	9·8	6·6	6·6	6·2
Hot return fines in mix, %	33·1	28·6	36·8	37·2	26·5	43·5	20·4	33·8	30·4	28·8	27·7	32·2
Cold return fines in mix, %	7·3	8·9	6·2	6·3	7·8	6·7	8·9	...	7·3	6·9	7·3	6·2
Flue dust in mix, %	2·4	2·4	4·4	4·3	5·0	3·1	3·7	3·7	4·0	9·0	3·8	4·3
Coke in mix, %	4·4	3·9	3·5	3·5	4·1	2·9	3·7	4·2	3·7	3·4	4·2	3·4
Fan inlet temperature, °C	108	104	114	150	138	157	115	119	125	80	103	129
Fan inlet suction, in. w.g.	25·0	26·6	26·0	22·4	23·9	22·9	26·5	25·7	25·2	29·2	27·0	25·0
Total air flow at fan, 10^3 ft³/min. (S.T.P.)	125·3	120·2	116·0	112·6	112·5	120·0	113·7	117·0	118·0	113·8	116·0	109·0
Air flow through sinter bed, 10^3 ft³/min (S.T.P.)	73·3	66·0	62·4	63·8	61·7	71·0	59·1	63·8	65·5	55·8	60·4	56·0
Fan air per ton, 10^3 ft³ (S.T.P.)	49·1	48·5	46·6	45·0	43·0	47·3	45·8	44·0	46·3	46·7	50·8	44·2
Bed air per ton, 10^3 ft³ (S.T.P.)	28·7	26·6	25·1	25·6	23·6	28·0	23·8	23·9	25·7	22·7	26·4	22·7
Apparent permeability, B.P.U.	111	103	100	107	104	113	98	103	105	93	99	98
Average bed permeability, B.P.U.	74	63	61	69	64	77	56	63	65	49	56	55
Sinter fan kilowatts	1000	982	964	897	918	984	944	960	973	955	932	900
Time on strand, min	15·4	16·3	15·9	15·7	14·7	15·0	15·7	14·7	15·1	15·8	17·5	16·0

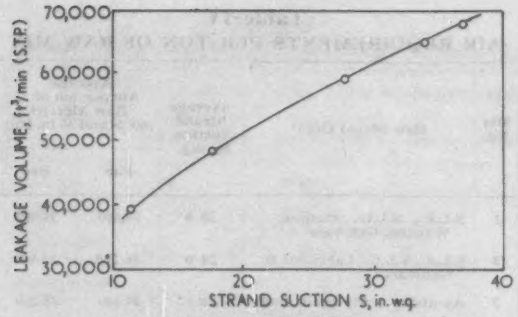


Fig. 3—Plant leakage at varying strand suctions. Results obtained on a stationary strand sealed with brown paper

on the first trial showing a range of 3–6% moisture within 20 min. For this reason only occasional determinations were made during the assessments, and it has not been thought fit to include the results in Tables II and III. The extreme values encountered were 3% and 9% and the average value over all assessments was 7%.

OBSERVATIONS AND RESULTS

The first trial was carried out over twelve working days between 7th December, 1954, and 2nd February, 1955, and the second during the period 19th November to 27th November, 1956. Average conditions observed during the test periods indicated are shown in Table II for the first trial and Table III for the second trial, together with the derived data calculated from the basic equations

(*a*) *Air requirements per ton of raw mix*

$$V = \frac{60F}{I} \text{ ft}^3 \text{ (at 60° F and 30 in. Hg)}$$

(*b*) *Permeability* $P = \frac{F}{A}\left(\frac{h}{s}\right)^{0.6}$ B.P.U.

where F = air flow, ft³/min at 60° F and 30 in. Hg
A = area of strand, ft²
I = material input rate, tons/h
h = depth of bed (before ignition), in.
s = suction, in. w.g.

Strand Utilization

In general the practice during the first trial was to use the entire strand for sintering. There were thus no cooling windboxes, and strand utilization was 100%. Under these conditions, fluctuations in mix composition, permeability, and feed rate made it inevitable that from time to time unsintered material would be discharged from the end of the strand to be screened out as return fines. Although any unburnt fuel in this material would cause a slight increase in the coke content of later mixes, calculation showed that the increase was not as great as that which occurred as the result of fluctuation in the coke feeder-table rate. As the flame front was usually right on the grate at the discharge end of the strand, it has not been considered necessary to make any correction to the 'air per ton' figures given in Table II for the odd occasions when a small amount of unsintered material was leaving the strand. During the second trial, the actual temperature in the last three windboxes was measured in conjunction with visual observations of the flame front, at the discharge end of the strand. From the results it was considered that sintering was actually completed over windbox 20, when the temperature in windbox 19 was approximately 20° C higher than that in windbox 20. It is suggested that this condition could be caused by an increase in the leakage of air into windbox 20 over the dead plates at the end of the strand. Since in most of the assessments during the second trial, windbox 19 was the hottest by about 20–30° C no correction for cooling air has been made to the 'air per ton' figures given in Table III, and it is considered that in general strand utilization is in the region of 100%.

Air Requirements per Ton of Raw Mix

In previous sinter-plant assessments the total volume of air passing through the windlegs was measured and divided into sintering and cooling air, according to the position of the hottest windbox. These air flows were then used to calculate the specific volumes of sintering and cooling air per ton of raw mix input to the strand.

Since in general the whole strand is used for sintering at Shotton, the second term is virtually non-existent and, as the measurement of all the windleg air flows was impracticable, the total air flow at the fan has been used to calculate the quantity termed 'fan air per ton'. This is the specific volume of air at the fan per ton of raw mix fed to the strand. Later tests to determine the plant leakage at various strand suctions made it possible to calculate a figure for the actual air flow through the bed and thus the specific volume termed 'bed air per ton of raw mix'. Table IV shows the average fan and bed air per ton for the basic mixes used during the two assessment trials shown in Table I.

Over all the assessments the fan air per ton varied between 44,000 and 68,000 ft³ (S.T.P.*); this figure, however, includes a variable amount of leakage air which increases with increasing strand suction. Values for the bed air per ton which excludes this leakage show a variation between 22,700 and 28,000 ft³ (S.T.P.). The addition of 5% basic slag to mix 2 and 9% flue dust to mix 5 had no significant effect on the bed air per ton. Over the 25 assessments

* S.T.P. = 60° F and 30 in. Hg.

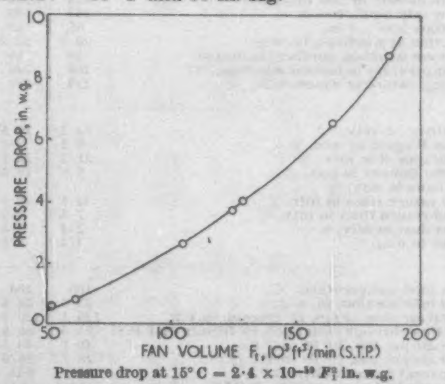


Fig. 4—Relationship between pressure drop and fan volume at 15° C. Pressure drop measured between fan and strand

made during the two trials, the bed air averaged 25,000 ft³ (S.T.P.) per ton of raw mix fed to the strand, 72% of the results being within ± 5% and all the results within ± 10% of this value. It is considered, therefore, that the bed air per ton is reasonably constant over the range of operating variables experienced during the trial and that the fan air per ton increases with increasing strand suction solely owing to the greater leakage incurred. It is interesting to note that the figure calculated by Voice *et al.*[1] of 25,150 ft³ (S.T.P.) for the ' air into the bed ' per ton of raw mix at Appleby-Frodingham compares very closely with that obtained at Shotton of 25,000 ft³ (S.T.P.) for the bed air per ton.

Plant Leakage

With the strand sealed with brown paper, the leakage of air into the plant was measured at varying suctions. The strand was completely covered with 3-ft wide strips of stout brown paper. Three strips were laid the full length of the strand, providing generous overlaps so that, when suction was applied under the strand, a good seal was obtained. By manipulating the fan vanes the suction was varied in stages from 11 to 37 in. w.g. and the total leakage volume measured at the two fan main Venturis. The results obtained during the first trial are shown plotted in Fig. 3, from which the leakage air flow is given by the expression

$$\text{Leakage air flow} = 11{,}300\sqrt{(\text{Strand Suction})} \quad \text{ft}^3/\text{min (S.T.P.)} \quad \ldots\ldots (1)$$

This test was repeated on the second trial and the value obtained for the constant was 11,500.

Both tests were carried out after a weekly shutdown when the strand was cold and stationary and so they cover only one particular set of pallets. However, as no effort was made to ensure that the seal bars had fallen correctly into place the strand was stopped at random in both tests; the results are considered to be representative of continuous operation. The total leakage so obtained includes the leakage through the pallet seals, over the dead plates at each end of the strand, at the dustlegs and cyclone dustcatchers,

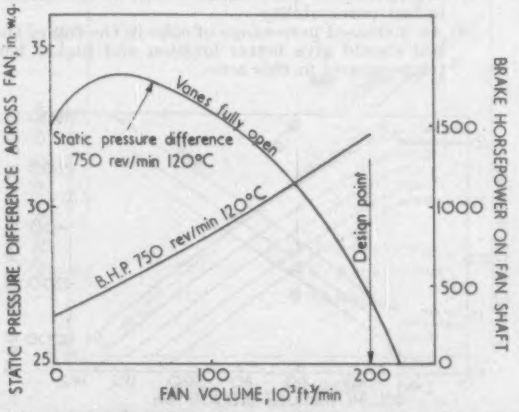


Fig. 5—Fan makers' estimated fan characteristic curve for the original impeller (volume at 120° C and 27 in. w.g. suction)

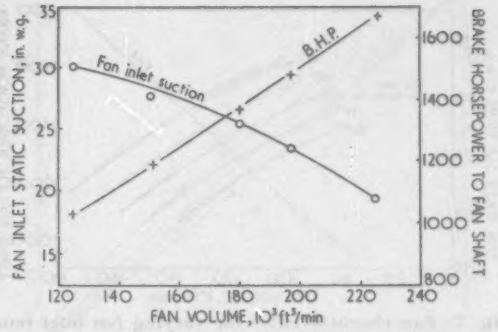


Fig. 6—B.I.S.R.A. test curve showing relationship between fan volume and fan inlet suction with fan vanes fully open (fan volume at 120° C and 30 in. Hg, as derived from cold-air tests)

and in the ducting to the fan. It does not include any leakage incurred through cracks in the bed or side leakage due to shrinkage of the mix during sintering.

Measurement of Pressure Drop

To obtain the pressure loss between the strand and the fan at varying air flows the suctions under the strand and at the fan were measured simultaneously during the leakage test. Thereafter, to obtain a wider range of air flows, the paper was removed from the strand in stages. The results obtained during the first trial and confirmed on the second are shown in Fig. 4, from which the pressure loss when the air flowing is at 15° C is given by the expression

$$\text{Pressure loss} = 2{\cdot}4 \times 10^{-10} F_1^2 \text{ in. w.g.}$$

where F_1 is the total S.T.P. volume flowing at the fan. As the pressure loss is proportional to the absolute temperature of the flowing medium,[4] the pressure loss, when the temperature of the flowing medium is T° C, is given by

$$\text{Pressure loss} = 2{\cdot}4 \times 10^{-10} F_1^2 \frac{(T + 273)}{288} \text{ in. w.g.} \quad \ldots(2)$$

This equation has not been corrected for buoyancy since in this case the effect is negligible.

Fan Performance

Figure 5 shows the makers' estimated fan characteristic curve at 120° C and 750 rev/min with the vanes in the fully open position, the ordinate being the total static suction across the fan. In attempting to predict plant performance, however, it is considered that a more useful relationship would be that between the total fan volume and the fan inlet suction. In view of this it was decided to carry out a fan test during the second trial to determine the above relalationship with the fan vanes in the fully open position. It should be noted that the fan had been fitted with a new impeller before the second trial. The test was carried out after the leakage test and in conjunction with the pressure-drop test, variation in air flow being achieved by progressively removing the brown paper from the strand. The results are shown in Fig. 6 with the fan volume expressed in ft³/min at 120° C and 30 in. Hg.

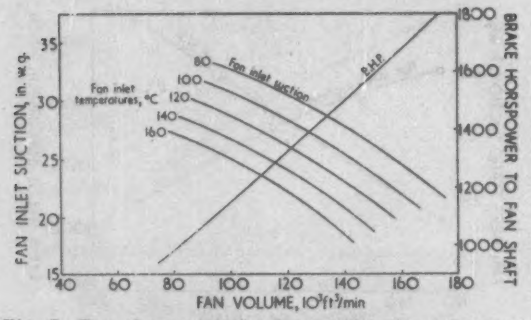


Fig. 7—Fan characteristics for varying fan inlet temperatures (volume at 60° F and 30 in. Hg)

The family of curves in Fig. 7, calculated from the B.I.S.R.A. test results in Fig. 6 in accordance with British Standard 848 : 1939 *Testing of Fans*, show the fan inlet suction-volume characteristics for fan inlet temperatures between 80° and 160° C with the volume expressed in ft³/min. at S.T.P. Only one curve has been drawn on Fig. 7 for the brake horsepower to the fan shaft, because at different fan inlet temperatures the relative fan efficiency almost compensated for the variations to air horsepower caused by the change in air density. The curve shown is the actual b.h.p. absorbed when the fan inlet temperature is 120° C; the maximum departure from it over the range shown was ± 2%.

Air Flow through the Bed

The total air flow at the fan is made up of the air flow through the bed and a variable amount of leakage, depending on the strand suction. As strand utilization at Shotton is generally about 100%, it was considered useful to calculate the bed air flows as a function of the strand suction for varying fan-inlet temperatures. The calculation entails the use of the leakage and pressure-drop equations (1) and (2) and assumes that the plant leakage is the same on a hot moving strand as that measured on a cold stationary strand. The curves obtained are shown in Fig. 8, together with the b.h.p. at the fan shaft for fan inlet temperatures of 80°, 120°, and 160° C. Provided that the vanes are in the fully open position, these curves should enable the operator to obtain a reasonably accurate spot value for the air flow through the bed and hence the average permeability and bed air per ton. Comparing Fig. 8 with the trial results in Table III shows that in general the agreement is fairly good.

Windleg Air Flows

During the second trial, air-flow measurements were made simultaneously at windlegs 2, 8, 13, and 18, and in general the air-flow pattern along the strand was found to be very erratic. This could have been due to fluctuations in mix permeability from pallet to pallet, to the variation in leakage past the drop-bar seals off each pallet, or to cracks in the bed. It is possible that the air flow through No. 2 windleg could be measured to give an indication of the mix permeability immediately after ignition, but it is considered that a more reliable and useful figure for plant control would be the average bed permeability, calculated from the total air flow through the bed.

Permeability

Since the windleg air flow was not measured, the fan air flows and suctions, which include leakage, were used to calculate the figure termed ' apparent permeability ' in Tables II and III. The corresponding ' bed permeability ' was calculated from the measured strand suction and the air flow through the bed obtained from the fan air flow by subtracting the leakage. Tables II and III show that the bed permeability was in most cases almost half the apparent permeability because of the exclusion of leakage, which under normal operation was approximately 50% of the total air at the fan. The values obtained for bed permeability compare favourably with previously reported results on the B.I.S.R.A. experimental sinter box for the average sintering permeability of foreign ores. Figure 9 has been plotted to show the effect of increasing bed permeability on the total material input rates for 10- and 12-in. beds. Assessments when windbox 18 was the hottest have been excluded from Fig. 9 as the material input rate in such cases could have been increased. The variation of return fines percentage in the mixes was not great enough to show any correlation with permeability except in the case of mix 1, where increasing circulating load was accompanied by an increased bed permeability. In general the bed permeabilities obtained on the second trial were higher than those experienced during the first trial. This could be due to the fact that during the second trial there were no Sierra Leone concentrates in the mixes used, and that approximately 83% of the circulating load was in the form of hot return fines.

Bed Segregation

Vertical segregation of a sinter mix is considered to be desirable for the following reasons[1]:

(*a*) Since the smaller particles are on top of the bed, the top surface is smoother
(*b*) Large material of reduced coke content at the bottom of the bed forms a hearth layer which protects the grate bars
(*c*) Segregation of sizes should result in an increase in bed permeability
(*d*) An increased percentage of coke in the top of the bed should give better ignition and higher bed temperatures in this zone.

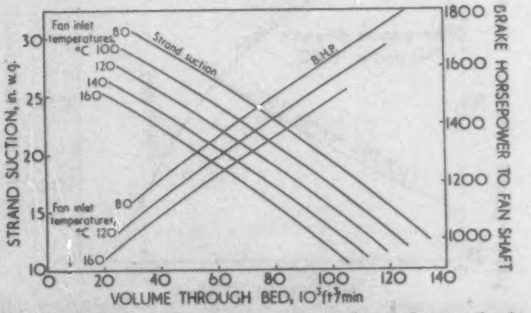


Fig. 8—Relationship between strand suction and air flow through the bed (volume at 60° F and 30 in. Hg)

Tests were carried out during both trials to determine the size segregation in the raw mix, and during the second trial further tests were carried out to determine the coke segregation. A multi-shovel was used which gave samples simultaneously at six vertical levels in the bed; these samples were sieved whilst moist through a $\frac{1}{4}$-in. B.S.S. mesh and the proportion by weight of $+\frac{1}{4}$ in. material in each sample was found. Samples taken from selected tests were analysed for carbon content in the laboratory. The mean of all tests was taken for each trial and the results are plotted in Fig. 10, which shows the relation between the cumulative percentage of $+\frac{1}{4}$-in. material plotted against the height of the bed in inches from the grate bars. On the same figure is the cumulative carbon percentage (excluding carbonate) and for comparison the line for a homogeneous bed, i.e. the cumulative percentage increasing uniformly with bed height. No attempt has hitherto been made to make a quantitative assessment of the degree of segregation. The amount of segregation occurring in a sinter bed may be looked on as a function, first, of the amount of oversize (in this case $+\frac{1}{4}$ in.) present in each layer of the bed and, second, of the distance of these particles from that position which they would occupy in a homogeneous bed. A useful measure of the amount of segregation would therefore be the product of these two factors (say Z). For a bed height h containing an average oversize fraction ϕ, if the excess or deficit of oversize at different levels x from the band of zero segregation is y (Fig. 11), it can be shown that

$$Z = \sum_{-a}^{h-a} yx\,\delta x$$

where a is the distance of the band of no segregation from the top of the bed. The value of Z is dependent on the average concentration of the oversize fraction in the bed and upon the numerical value of h. To minimize this effect, Z has been calculated for the average oversize fraction numerically equal to 100 and for a bed height of unity. Curves 1, 2, and 4 in Fig. 10 correspond to Z values of 6·0, 2·3, and − 1·2 respectively.

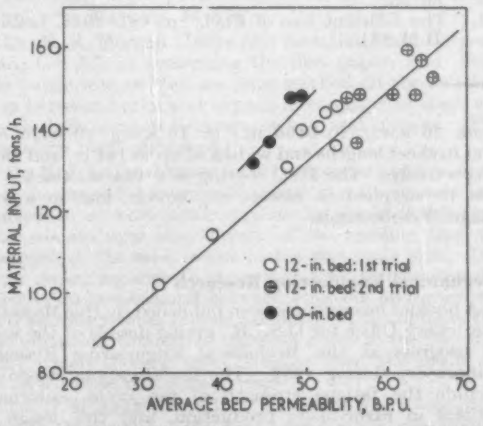
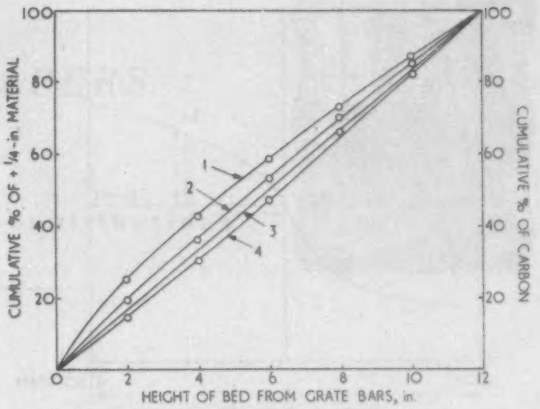


Fig. 9—Relationship between hourly input of material to the strand and average bed permeability



1. Size segregation, first trial
2. Size segregation, second trial
3. Homogeneous bed
4. Carbon segregation, second trial

Fig. 10—Bed segregation; comparison between average Shotton mix and fully non-segregated mix

Sinter Cooling

The hot sinter leaving the strand passes over a Schenck vibrating screen which removes the return fines, and the $+\frac{1}{2}$ in. fraction enters the cooler via a chute. The cooler is a forced-air convection rotary type, built by Head Wrightson and Co., Ltd., and is designed to cool the sinter sufficiently to permit its transport on rubber-belt conveyors to the furnace plant. The cooler is supplied with air from four Aerex fans in parallel, each rated at 50,000 ft³/min at 7 in. w.g. and driven by 75-h.p. motors. Usually only three of the four fans are used. Air enters the cooler through a 10-ft dia. main which is connected to the windbox through a water seal; the air then passes via two rows of downward-facing louvres through the hot sinter. Tests were carried out on the first trial to determine the temperature of the sinter entering the cooler and also of the return fines leaving the Schenck screen, by using a large calorimeter insulated with slag wool. The quantity of water in the calorimeter was 60 lb, and approximately 20 lb of sinter or return fines were used for each test. Eight tests were carried out on the sinter and its temperature was found to vary between 200° and 750° C, giving an average sinter temperature of 460° C. Six tests were made on the return fines leaving the screen before the cooler and the temperature of the fines was found to be between 200° and 460° C, the average being 280° C. This lower average temperature is due to the fact that the greater proportion of return fines comes from the cooler top layers of sinter, which are not usually as strong as the bottom layers formed at a higher temperature.

The temperature of the sinter leaving the cooler was not measured but it could easily be held in the hand. During the above tests three fans were in use and the average total air flow was 147,000 ft³/min; the cooler windbox pressure was 4·5 in. w.g. and sinter throughput averaged 65–70 tons/h, giving a calculated power consumption for sinter cooling of 2·4 kWh/ton of blast-furnace sinter. The maximum capacity of the cooler cannot be estimated from the test results,

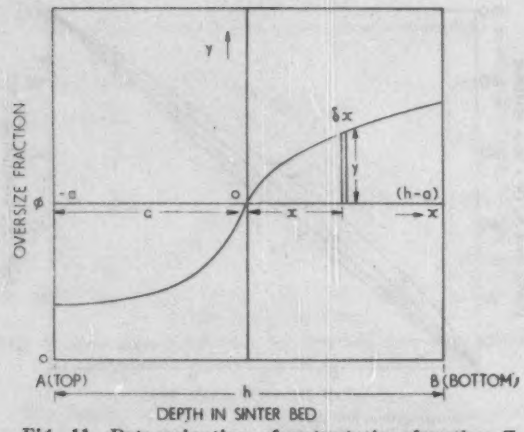


Fig. 11—Determination of segregation function *Z*

but it has operated satisfactorily at a throughput of 80 tons of blast-furnace sinter per hour with only two fans running. Sieve analyses carried out on the cold discharge sinter showed that an average of 16% was $-\frac{1}{4}$ in.

CONCLUSIONS

The assessment trials at Shotton have shown that the air flow at the fan per ton of raw mix passing over the strand increased with increasing strand suction from 44,000 ft³ at 21·5 in. w.g. strand suction to 68,000 ft³ at 34 in. w.g. owing to the increased leakage incurred at the higher suctions. The bed air per ton of raw mix, however, which excludes the leakage air, was substantially constant, over the range of conditions experienced during the two trials, at 25,000 ft³ and the principal factor controlling the rate of sinter production was therefore the air flow through the bed. During the first trial the average bed permeability varied between 25 and 54 B.P.U. On the second trial, when no concentrates were used in the raw mix, the average bed permeabilities were substantially higher, ranging from 47 to 65 B.P.U. for assessments when sintering was completed at the end of the strand.

Although the percentage of return fines in the raw mix varied for each assessment, the average value of 38·2% obtained on the second trial agrees closely with the average value of 39·5% measured during the first trial. The fact that approximately 83% of the circulating load used during the second trial was in the form of hot return fines had no noticeable effect on the bed air requirements per ton of raw mix, although it may have been partly responsible for the higher average bed permeabilities. In all cases higher average bed permeabilities were accompanied by increased air flows through the bed and hence greater material input rates. The leakage volume was measured and found to be proportional to the square root of the strand suction. Over the range of plant operation experienced during the two trials the leakage varied from 44% of the total air flow at the fan at 20 in. w.g. strand suction to 66% of the total air flow at 34 in. w.g. strand suction.

On the second trial a fan test was carried out and the air flow through the bed was calculated for different fan inlet temperatures as a function of the strand suction (Fig. 8) to facilitate speedy determination of the average bed permeability and bed air per ton. The sinter cooler was tested and found to operate satisfactorily and, by eliminating the necessity for sinter cooling on the strand, it was possible to maintain strand utilization in the neighbourhood of 100% In general the second trial has confirmed the results obtained on the first trial. The increased average bed permeabilities have been accompanied by higher material input rates and the air requirements per ton of raw mix have remained virtually constant.

Acknowledgments

The authors wish to thank the management of John Summers and Sons, Ltd., for permission to carry out these trials and to publish this paper. They also gratefully acknowledge the fullest co-operation of the works staff throughout the trial.

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New Plastic-coated Steel

A new British material material called " Stelvetite," a plastic-coated steel sheet, with many potential applications in industry, has recently been put on the market.

Stelvetite, which has been developed exclusively by John Summers and Sons Ltd. in conjunction with B.X. Plastics Ltd., is strip-mill cold-reduced steel with a specially formulated Velbex PVC coating. The reverse side of the sheet can be either a bonderized steel or electro-zinc-coated surface. It can be bent, formed, seamed, deep-drawn, joined, and welded without damaging the coating; it has good electrical insulating properties and is highly resistant to acids, alkalis, greases, detergents, weather, humidity, and abrasion. It does not support combustion, and is stable at higher temperatures than PVC alone. It is available in steel gauges from 26 s.w.g. (0·0196 in.) to 16 s.w.g. (0·0625 in.), and in sheet lengths and widths of up to 144 in. and 48 in. respectively. The PVC coating is 0·014 in. thick. It can be supplied in almost any colour, and in a wide range of embossings.

Mechanical Engineering Research

A booklet has recently been published by Her Majesty's Stationery Office for D.S.I.R., giving details of the work in progress at the Mechanical Engineering Research Laboratory during 1956. The investigations described include the fatigue strength of pin-joints, automatic control in razor-blade production, and the design of extrusion dies. The report is obtainable from H.M.S.O., price 4*s*.

DISCUSSION ON PAPERS

Discussion at Meetings · Written Contributions

Annual General Meeting, 1957

The Eighty-eighth Annual General Meeting of The Iron and Steel Institute was held on Wednesday and Thursday, 22nd and 23rd May, 1957, at the Offices of the Institute, 4 Grosvenor Gardens, London, S.W.1. Dr. H. H. Burton, C.B.E., the Retiring President, was in the Chair at the beginning of the Meeting, his place being taken later by Mr. A. H. Ingen-Housz, the new President.

Discussions at some of the technical sessions were published in the November, 1957, issue of the *Journal*; further discussions are given below.

JOINT DISCUSSION ON BORON STEELS

This discussion was based on the following papers (the dates of publication in the *Journal* are given in parentheses):

"The Strain Ageing of Boron-treated Low carbon Steels", *by E. R. Morgan and J. C. Shyne* (1957, vol. 185, February, pp. 156–160).

"The Physical Metallurgy of Low-carbon, Low-alloy Steels containing Boron", *by K. J. Irvine, F. B. Pickering, W. C. Heselwood, and M. Atkins* (1957, vol. 186, May, pp. 54–67).

Dr. **E. R. Morgan** (Jones and Laughlin Steel Corporation, U.S.A.), in presenting the first paper, said: Since the paper was written we have worked on the relationship between boron and oxygen in commercial steel, and on the relationship between carbon and oxygen. This has since been published.[1]

Dr. **K. J. Irvine** (United Steel Companies Ltd.), presenting the second paper, said: Since the paper was submitted, more work has been done on steels of this type, and we are now very firmly of the opinion that the strength of the steel is due to the fine grain size. In a later paper we hope to show the very clear relationship which can be obtained between strength and grain size in a bainitic ferrite, but we are firmly of the opinion that the enhanced strength of the steel is due to the fine grain size, which is very much smaller than the grain size obtained from polygonal ferrite.

Dr. **G. M. Leak** (B.I.S.R.A.): I should like to congratulate Dr. Morgan and Mr. Shyne for a major contribution to the problems of deep-drawing steels. A number of laboratories in the U.K. have been interested in ageing and the production of non-ageing steels. Whilst some success has been reported with regard to methods for reducing the effects of ageing, this vast influence of boron is potentially much more significant than that of, for example, vanadium, provided that the mechanism for introducing the boron is not too expensive or difficult.

In the B.I.S.R.A. laboratories we have tackled the problem of boron in mild steel somewhat differently from Dr. Morgan. Internal friction methods were used to find out whether boron formed an interstitial or a substitutional solid solution. The results, for material containing less than 0·001% nitrogen, about 0·001% carbon, and about 0·004% boron in solution, showed that boron formed an interstitial solution in alpha iron and, furthermore, that boron, in solution, contributed to strain ageing. We had previously shown a correlation between strain ageing as observed by internal friction methods and strain ageing observed by more orthodox yield-point measurements. This ageing effect of boron might be of interest to the present results. Table IV shows that, particularly for the alloys series *H*, addition of more than about 0·02%B increases the ageing index. If the results of Table IV are plotted in the form ageing index versus boron content, it can be seen that the ageing index has a minimum value for about 0·02% B. Have the authors any information about the ageing rates for these alloys? It is known that the activation energies for diffusion of carbon, nitrogen, and boron in iron are approximately 20·2, 18·4, and 17 kcal respectively. It may thus be possible to discover which element is primarily responsible for ageing in alloys containing large amounts of boron.

Fig. A—0·1% C, 0·5% Mo steel in normalized condition, showing large polygonal ferrite and pearlite; Formvar replica × 3000

In iron–carbon alloys where the carbon has been precipitated as carbide particles, strain ageing can cause some of the particles to redissolve to allow formation of dislocation atmospheres. It is possible that the ageing observed in the higher-boron alloys is caused by a similar effect. This would require some influence of boron on the size of the particles precipitated during box annealing. Dr. Morgan suggested that the precipitated particles were not iron boride, but were complex carbonitride particles containing boron. Is there any further information about this point, or about the influence of boron on the precipitated particle size?

A minor point is that Dr. Morgan did not observe a yield point in his specimens, when the ageing was less than 3500 lb/in². This is contrary to our own results, but may be simply a question of testing procedure. It would, however, be interesting to know if this value for the ageing index can be used to decide whether or not material will be satisfactory for deep drawing. Such a criterion might influence the effort to be devoted to the elimination of ageing.

The remaining point I would like to raise concerns strain-age embrittlement. Is there any information available on the effect of boron on the impact strength of mild steel? Such information would be valuable in any study of the ductile–brittle transition in steel.

The paper by Dr. Irvine and his co-workers represents an extremely valuable collection of data on steels containing boron. I was very impressed by the careful work they reported. My only comment concerns the nature of the precipitated phase. They reported it as iron boride. Can the authors give any more details about (*a*) identification of the boride, and (*b*) whether or not precipitation was observed inside the fine-grained material after transformation?

Dr. **B. Hundy** (Steel, Peech and Tozer): I propose to confine my remarks to the paper by Morgan and Shyne, which confirms conclusively what many of us have suspected for some time, that boron prevents strain ageing in mild steel. With regard to the measurement of the degree of strain ageing, Dr. Leak has referred to the 'magic figure' of 3500 lb/in². We should regard that as somewhat high. We tend to think of a non-ageing steel as having an index figure of about 5%, or about 2500 lb/in². This figure depends to some extent on whether bar or strip material is being tested.

One of the points which the authors have brought out is the usefulness of the residual elements, especially chromium, in preventing carbon strain ageing in mild steel. The acceleration of precipitation of carbon from solution in these steels by these elements seems to be very important, and it seems a good thing that commercial steels do contain residual elements.

The point which Dr. Leak brought out is almost certainly boron strain ageing starting with more than 0·02% B. There is rather a similar effect, I am told, in creep work. As one starts adding boron, the creep resistance first drops off and then, as the boron content is increased, the creep strength rises again. I imagine that the excess boron goes into solid solution and ties up the dislocations in the same way as nitrogen.

The effect of boron in improving the ductility and tensile strength of steel is interesting. Have the authors any explanation of this? I favour the view that the improvement in the properties is due to the removal of the nitrogen from the solid solution as the nitrogen would tend to harden the steel. The strain ageing, the tensile strength, and the ductility all follow the same type of curve in these steels. The tensile strength drops to a minimum at 0·01% B and then increases again, while the ductility shows an inverse effect.

Dr. Morgan has told us a little about the results he obtained in practice. Apparently many difficulties were met with, and it would be of value to have further details. He emphasized the need for the steel to have the correct oxygen content and it is obvious that a wrong boron/oxygen balance may give a rimming steel which strain-ages or a killed steel which does not strain-age. Control of the steelmaking process and of additions has to be very close indeed, and generally our control is not at present quite good enough for this purpose; in particular, the oxygen must be controlled much more closely.

Looking at the results given, I should like to ask whether, in an O.H. steel containing, say, 0·005% nitrogen, we might sometimes need more than 0·007% B. The results of the authors' ageing tests on the boron-free steels in this paper suggest that, in the two series *H* and *L*, the free nitrogen content may have been only of the order of 0·003%, the rest being combined with the 0·01% aluminium present in these steels. My reason for thinking this is that, except for series *E*, the fall in ductility and rise in strength on strain ageing are lower than one would expect for a steel with a nitrogen content of 0·005%. On this argument, therefore, it might seem that perhaps 0·012% B would be needed to prevent ageing in a commercial rimming steel and this may upset the oxygen/boron balance. It was surprising to learn that a high boron addition was not needed with O.H. steels. Is that accounted for by the aluminium capping?

Dr. **J. Nutting** (Cambridge University): Dr. Irvine and his co-authors refer in their paper to work which Dr. Siriwardene and I have carried out on boron-containing steels at Cambridge.

We have been investigating, with the aid of the electron microscope, the microstructures of boron steels. With a steel containing 0·1% C and 0·5% Mo, the microstructure in the normalized condition shows the characteristic polygonal ferrite with areas of fine pearlite. An example is given in Fig. *A*. With a steel of similar composition but containing 0·003% B in addition, the microstructure in the normalized condition consists of small ferrite grains of an acicular shape together with

areas of fine pearlite, as shown in Fig. *B*. By varying the rate of cooling from the austenitic region a wide range of ferrite grain sizes may be obtained. We then determined the mean ferrite grain diameter after different cooling treatments and found that there is a linear relationship between the reciprocal of the square root of the ferrite grain diameter and the Vickers hardness. It is also possible to obtain a fine ferrite grain size in the steels by quenching to martensite and then tempering. When a boron-containing steel is quenched and then tempered back to the same hardness as that obtained by normalizing, it is found that the mean ferrite grain sizes in the two conditions are the same.

It therefore appears that in a boron-containing steel we can produce a bainitic ferrite which has a structure equivalent to that of a quenched and tempered steel. As more knowledge becomes available of the properties of bainitic ferrites it seems that it may be possible to go directly from austenite to the type of structure we require in a finished steel, without intermediate martensite. Thus the whole technique of steel heat-treatment may be changed as a result of the authors' investigations.

From the results given in Figs. 20 and 22, the authors have tried to indicate that time and temperature are directly interchangeable in a tempering process on alloy steels. From a detailed examination of the microstructures of tempered alloy steels I am firmly convinced that such a view is mistaken; changes occur in a long time at low temperatures which are not found in short times at high temperatures, an effect which is particularly marked in steels showing secondary hardening. If diagrams similar to Figs. 20 and 22 are published in future, it should be standard practice to indicate the temperature at which each point on the diagram was obtained.

Mr. **A. J. K. Honeyman** (Steel Company of Wales Ltd.): The behaviour of boron, as shown by Dr. Leak, is in sharp contrast to that of aluminium, where a sudden drop in ageing index takes place with about 0·025% Al, and increasing amounts do not cause further change.

The apparent delicate balance in the distribution of boron between oxygen and nitrogen is another problem in the production of these steels on a commercial scale. However, the subject is of such practical importance that it behoves steelmakers concerned to investigate the possibilities to the fullest extent.

CORRESPONDENCE

Mr. **A. J. K. Honeyman** (Steel Company of Wales Ltd.) wrote: It is almost 20 years since boron first made its appearance in the field of ferrous metallurgy. It was then claimed to increase markedly the hardenability of structural alloy steels. At that time, in the U.S.A., whence the claims originated, not much importance was attached to the notched-bar impact test. In the U.K., however, the test was part of the specification for these steels, and trouble with impact values was experienced with boron steels. It was found that good impact values could be obtained provided that the initial quenching gave full hardening. With this background, Bardgett and Reeve in 1949 published their paper on the mechanical properties of low-carbon–low-alloy steel containing boron. It was most remarkable to find that a steel of 40 tons/in^2 tensile in the as-rolled condition could be welded without giving hard-zone cracking. Here, apparently, boron plays a somewhat different role, in that it is used to avoid complete hardening.

Now, eight years later, we have a complete explanation for which Dr. Irvine and his co-authors have to be congratulated. But one is left with a feeling of regret that the explanation did not come before the discovery!

In the Bardgett and Reeve paper, the impact values of some experimental steels appear to show a sudden

Fig. B—0·1% C, 0·5% Mo, 0·003% B steel in normalized condition, showing fine-grained bainitic ferrite; Formvar replica × 3000

drop at 0·18% C. Can the present authors make any comment on this ? One other point, on p. 66 the authors discuss reasons for the high strength of bainitic ferrite, which they suggest is not due to strain-induced hardness. Is the specific volume of bainitic Fortiweld the same as that of the steel in the fully annealed condition ?

The paper by Morgan and Shyne deals with an entirely different effect and application of boron, arising from its useful property that in fully killed aluminium-containing steels it combines with iron, but in the absence of aluminium it combines with nitrogen. The experimental work described deals only with oxygen-free steel. The problem of strain ageing of low-carbon rimming steels arises because of the difficulty of fixing the nitrogen without first fixing the oxygen. In theory, vanadium ought to work, but in practice it has not been successful.

I have had the opportunity of studying the further work mentioned by Dr. Morgan, and it does appear that, with careful control, additions of boron and aluminium can produce non-ageing effects without detriment to the rimming properties. If such steels can be produced on a commercial scale without too many rejects, a very important contribution will have been made to the metallurgy of deep-drawing steels.

Mr. **I. Codd** and Professor **N. J. Petch** (Leeds University) wrote: With regard to the paper by Morgan and Shyne, we should like to refer to another effect of boron apart from that of removing nitrogen from solution in unkilled and semi-killed steels.

We have examined the effect of boron ($\sim 0{\cdot}003$ wt–% total B) on the lower yield point (σ_{LYP}) of an annealed and slowly cooled low-carbon killed steel at 18° C, over a wide range of ferrite grain diameter l. This enabled us to estimate the constant k in the equation, [2, 3]

$$\sigma_{LYP} = \sigma_0 + kl^{-\frac{1}{2}}.$$

On annealing the steel at greater than about 910° C, it was observed that boron increased k, which is a measure of the strength of the dislocation locking[4], to a value considerably above that for killed and semi-killed steels of high total nitrogen content ($\sim 0{\cdot}008$ wt–% N). However, on annealing and similarly cooling this steel at $< 8°$ C/min from temperatures between 750° and

850° C, no effect of boron was observed, the value of k being that of an ordinary killed steel.

These results suggest that boron in solution can lock dislocations and hence produce some strain ageing. However, the rapid fall in solubility of boron to $< 0{\cdot}0004$ wt-% in α-iron at 710° C[8] indicates that the authors' box-annealing and our 750–850° C annealing treatments would be unlikely to retain enough boron in solution to produce a strain-ageing effect.

AUTHORS' WRITTEN REPLIES

Dr. **Morgan** wrote: I should like to make some general remarks about the types of boron compounds which might be encountered in carbon or low-alloy steels. At first sight, it appears strange that Dr. Irving should find that he needs 0·0007% effective boron to give hardenability whereas we[6] found that in 0·5% C steels only 0·0003% B was the optimum level. This boron level we referred to as 'effective boron content' and it is different from the soluble boron, because soluble boron can include a number of boron compounds.

In boron steel, we can determine spectrographically the total boron content, but it does not help us much in understanding the behaviour of boron steels. Boron may be present as elemental boron in solution or adsorbed at imperfections such as grain boundaries and dislocations; it may occur as B_2O_3 or as a complex carbide which is probably $Fe_3(C, B, N)$. Some boron may even exist as Fe_2B when the boron content is high.

Several of the forms of boron will be soluble in dilute acid. Elemental boron should be readily dissolved, as should B_2O_3, being soluble in water. Some of the complex carbides can be soluble, particularly if the dissolution takes place under oxidizing conditions. In this case, to report the soluble boron content can be misleading because it is not believed that B_2O_3 or the complex carbide represent effective forms of boron. Unfortunately, we know too little about boron compounds in steel to be able to separate them quantitatively.

Dr. Leak suggested that boron may give rise to finely divided carbide which would go into solution in the cold-worked material and then give rise to strain ageing. Our general conclusion was that the carbides which we obtained in the boron-bearing alloys were more massive and that there would be less tendency for small carbides. Subsequent internal friction studies with the alloys, which exhibited some strain ageing after box annealing, have shown that there is some interstitial element in solution but it has not been identified. It is unlikely that re-solution of carbides can account for the strain ageing and a more likely explanation seems to be that the higher boron content affects the precipitation kinetics of carbon or nitrogen during box annealing.

I do not think there is anything magical about the figure of 3500 lb/in² as the threshold ageing index for return of the yield point. We found this correlation but, with other test methods and other samples, we could get another figure. Dr. Hundy suggests 2500 lb/in² as the threshold value and that is probably as good a general value as the one which we suggest. The important point is that it does not seem necessary completely to eliminate strain ageing to avoid a return of the yield point. Moreover, a small amount of strain ageing does not result in a loss of ductility.

We agree with Dr. Hundy's suggestion that the beneficial effect of boron upon the ductility of low-carbon steels can be attributed to its removal of nitrogen from solution. Dr. Hundy raises the question of the amount of boron required to produce non-ageing open-hearth steels in contrast to the amount required in laboratory steels. It is important to realize that in the laboratory steels the aluminium content was obtained spectrographically and does not represent soluble boron; so that all of the nitrogen present in the alloys was a potential contribution to strain ageing. In commercial O.H. practice[1] apparently *less* boron is needed than in laboratory alloys. The reason is not yet known.

The comments by Mr. Codd and Professor Petch are appreciated, and the authors agree that it is unlikely that boron itself can be expected to result in strain ageing in box-annealed steels. As Wert[7] has demonstrated, precipitation of carbon and nitrogen from ternary iron–carbon–nitrogen alloys is complex; and the possibility exists that boron, which has such high solubility in Fe_3C, may affect the kinetics of precipitation of carbon and nitrogen. Even a slight increase in their supersaturation of ferrite would show up as a small strain-ageing effect.

Dr. **Irvine** wrote: Dr. Leak asked about the precipitate formed and the identification. The important point is that the precipitate formed at high temperature when the austenite was deliberately coarsened by heating at high temperature. Electron diffraction of extracted particles identified the precipitate as Fe_2B.

There has been some comment about the boron being interstitial. It must be remembered that in our work we are referring to the action of boron in austenite and not in ferrite. In our effectively deoxidized and denitrided steels, there is little doubt that boron is in interstitial solid solution in the austenite.

Dr. Nutting referred to the higher-strength bainitic steels which we are developing. These will be described in a subsequent publication, but it can be stated now that it is possible to produce bainitic steels covering the tensile-strength range from 40 to 75 tons/in². Dr. Nutting also raised the question of the validity of tempering curves using a combined time/temperature parameter. For any complete examination of the tempering characteristics of such steels it is necessary to determine isothermal tempering curves, and such information is now being collected. But it is still maintained that the use of combined time/temperature tempering curves enables a simple picture to be presented of the tempering characteristics which is quite valid when the shorter times are used. These shorter times are of interest from the viewpoint of industrial heat-treatment.

Mr. Honeyman asked for an explanation of the drop in impact properties which occurred when the carbon content is raised above 0·18%. If the microstructures of such steels are examined, it is found that at about 0·18% areas of higher-carbon martensite are formed owing to the segregation of carbon which occurs on cooling. This leads to reduced impact properties unless tempering is adopted. With regard to the strength of the ½%Mo–B steel there seems little doubt that this is due to the fine grain size of the bainitic ferrite. This is supported by the fact that the high strength is retained after tempering at temperatures up to 650° C, and the steel only softens when ferrite grain growth occurs. There is no significant difference between the specific volume and steel in the bainitic or fully annealed conditions.

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3. A. Cracknell and N. J. Petch: *Acta Met.*, 1955, vol. 3, pp. 186–189.
4. I. Codd and N. J. Petch: Unpublished work.
5. C. C. McBride *et al.*: *Trans. Amer. Soc. Metals*, 1954, vol. 46, pp. 499–520.
6. J. C. Shyne *et al.*: *Trans. Amer. Soc. Metals*, 1956, vol. 48, pp. 265–271.
7. C. Wert: *Acta Met.*, 1954, vol. 2, p. 361.

JOINT DISCUSSION ON THE ELECTRICAL RESISTIVITY OF STEEL

This discussion was based on the following papers (the dates of publication in the *Journal* are given in parentheses):

"Thermal Changes in Steels as shown by Resistivity," *by G. Bullock* (1956, vol. 183, August, pp. 362–367).

"The Effect of Quenching on the Thermal Conductivities and Electrical Resistivities of Steel," *by R. W. Powell* (1956, vol. 184, September, pp. 6–10).

"The Effect of Oil Quenching and Tempering on the Thermal Conductivities and Electrical Resistivities of Three Steels," *by R. W. Powell and R. P. Tye* (1956, vol. 184, September, pp. 10–17).

"Thermal Conductivity and Electrical Resistivity of a 0·4–0·5% Manganese Steel," *by R. W. Powell and R. P. Tye* (1956, vol. 184, November, pp. 286–288).

"Specific Heat and Resistivity of Mild Steel," *by P. R. Pallister* (1957, vol. 185, April, pp. 474–482).

Dr. **G. Bullock** (Birmingham University) presented his paper and Dr. **R. W. Powell** (National Physical Laboratory) presented his three papers. Dr. **P. R. Pallister** (College of Science and Engineering, Woolwich) was unable to be present to present his paper.

Mr. **W. C. Heselwood** (United Steel Companies Ltd.): The interest in these papers lies in the experimental methods and factual results concerning certain electrical and thermal properties of selected steels. They contain little discussion of the further value of the results.

Dr. Bullock emphasizes that he has been essentially concerned with the development of a high-precision experimental method for determining electrical resistance at high temperatures. Reading the paper one is aware of careful design and the consideration and evaluation of possible errors. I am sympathetic to the author's preference for the potential-fall method to the use of a Kelvin double bridge. In his search for a switch to handle 20–30A without introducing intermittent resistance changes in a low-resistance circuit, was a mercury switch tried ? I recall a similar problem although with lower current (10–15A) when we found that a good totally enclosed mercury switch did all that we wanted.

Referring to the same results, Dr. Bullock sometimes writes 'A_3 point' and sometimes 'A_3 range.' An explanation of the distinction between these two terms would be helpful. It is disappointing that although the author discusses the results on the four carbon steels (and indeed makes comparisons between the differential resistivity curves and inverse-rate thermal curves) none of these curves is shown. Even without seeing the curves, I would agree with the author's conclusion that the ends of transformations are frequently not well defined by electrical resistance.

I consider then that he has described a good experimental method for the precise determination of electrical resistivity figures when these are wanted for their own sake, but that the use of such results to define transformation ranges can be uncertain.

Dr. Pallister has been concerned with determining the true specific heat of a 0·13% C steel within the transformation range, separating this from that part of the heat supplied during heating which provides the heat of transformation. Perhaps an analogy would be trying to measure the amount of water added to drown a man in his bath while he is drinking the bath water !

As with Dr. Bullock in the case of resistivity, Dr. Pallister finds it difficult to locate the A_3 point exactly from specific heat figures. He also includes some thermal analysis figures but these have been obtained by equipment not specifically designed for the purpose and it is not surprising that interpretation is difficult, as pointed out in an excellent mathematical analysis by T. F. Russell.* The main purpose of this work was to determine the true specific heat of a steel up to 1000° C and the interesting conclusion is that, if the effects of heat of transformation are separated out, the curve is very similar to that for pure iron.

In the first two of the three papers with which Dr. Powell is associated, he refers to the fact that for many years the National Physical Laboratory has, on behalf of B.I.S.R.A. Thermal Treatment Committee, been building up thermal data on 22 selected steels. All were in a stable condition, annealed or fully tempered. The data were required to test theories and calculations of heat transfer in steel masses with important related subjects of temperature gradients and thermal cracking, and it was largely with the latter in mind that the Committee asked for thermal conductivity measurements in the hardened condition and showing the effect of tempering. Many people would have guessed that increased hardness, from whatever cause, is in general accompanied by increased electrical resistivity and decreased thermal conductivity. These papers now give quantitative information on the effects of hardening and tempering on thermal conductivity, electrical resistivity, and the Lorenz function. The results call for little comment except to express satisfaction that they have been determined and to note the quite reasonable constancy of the Lorenz function.

The authors draw attention to the presence of a maximum in the thermal-conductivity/temperature curves of these tempered steels. In the United Steel Companies' laboratories we have regularly noticed the same effects in hardened and tempered steels. Dr. Powell has published elsewhere a survey of thermal conductivity figures of many materials over a wide temperature range, both above and below atmospheric temperature, from which it might be concluded that all steels may show this maximum at some temperature.

In the third thermal conductivity paper, referring to a manganese steel, the authors record a difference between results obtained at two laboratories which the National Physical Laboratory set out to resolve. Those of us who know the National Physical Laboratory method in detail are aware of its precision and would hesitate

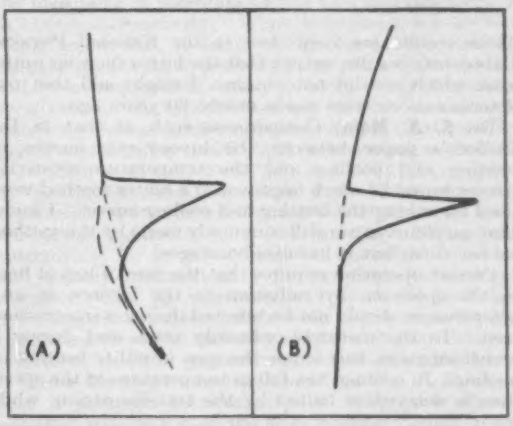
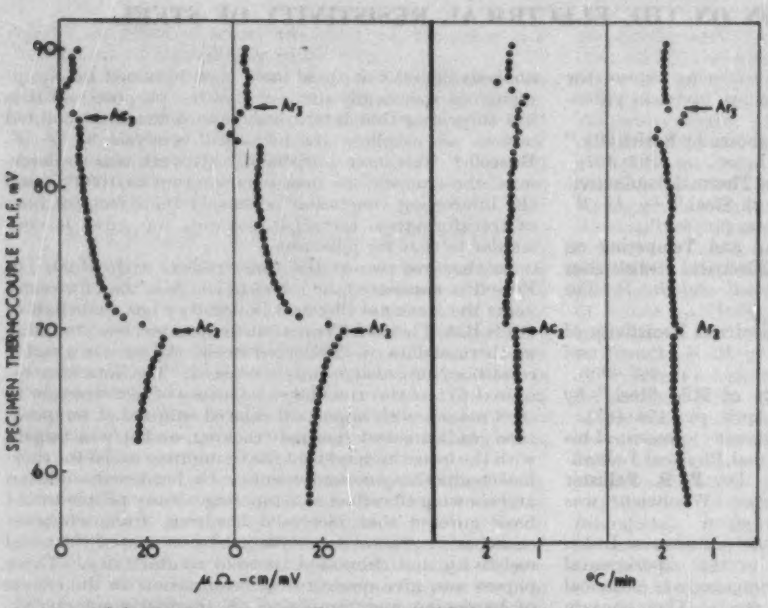


Fig. A—Inverse-rate cooling curve: normal pattern
Fig. B—Inverse-rate cooling curve by improved method

* *J. Iron Steel Inst.*, 1939, No. I, pp. 147P–176P.



Ordinate values of Specimen Thermocouple E.M.F. should be divided by 10

Fig. C—Differential resistivity/temperature and inverse-rate curves for Armco iron

to doubt its results. Furthermore, the Hogan and Sawyer results exhibit an unusual feature in that by comparison with the National Physical Laboratory results their higher thermal conductivity values are accompanied by higher electrical resistivity values. Normally these two properties move in opposite directions. On looking through our own determinations (United Steel Companies Ltd.) of thermal conductivity, I find results on two steels of analyses similar to that of the manganese steel under discussion.

Temperature, °C	Thermal Conductivity, J cm/cm² s°C	
	Steel I 0·08% C, 0·32% Mn	Steel II 0·10% C, 0·58% Mn
100	0·57s	0·54s
200	0·51s	0·51s
300	0·49e	0·47s
400	0·44s	0·43e
500	0·40e	0·40e

These results are very close to the National Physical Laboratory results, except that the latter show an initial kink which we did not obtain. I might add that our determinations were made nearly 20 years ago.

Dr. **S. A. Main**: Comparisons such as that in Dr. Bullock's paper between the inverse-rate curves of heating and cooling and the temperature/resistivity curves would be much improved if a better method were used for taking the heating and cooling curves. I know that such curves are still commonly made by the method he has used, but it has disadvantages.

Correct operation requires that the rate of loss of heat in the specimen by radiation to the furnace at any temperature should not be affected during a transformation. In the methods ordinarily used, and during a transformation, this is not the case in either heating or cooling. In cooling, the fall in temperature of the specimen is delayed or halted by the transformation, while that of the surroundings is proceeding with time. During, and for some time after, the transformation, the loss by radiation is therefore greater at any temperature than it would otherwise be, and the curve is distorted, particularly if there is recalescence. This is illustrated in Fig. *A*. There is therefore no true basis for estimating the evolution of heat in the specimen; the 'end point' of the transformation is also blurred. Similar considerations apply to heating curves as ordinarily carried out.

A more satisfactory method was suggested and applied by C. S. Smith.* It is capable of improvement. I have for example tried successfully an arrangement which cannot be described in detail for lack of time. The method involves the use of a taper-heated furnace in which the differential e.m.f. between a thermocouple in the specimen and one at the inner surface of the opposite furnace is maintained constant. This is accomplished by continuous adjustment of the position of the specimen up or down in the furnace, which can with advantage be effected automatically.

The cooling curve obtained thus was of the desired form illustrated in Fig. *B*. Similar adherence to a basic curve of radiation was obtained in the heating.

Dr. **Bullock**: Mr. Heselwood mentions the successful use of an enclosed mercury switch for switching currents of 15 A. In the present experiments attempts were made to reverse the current through the specimen using such a switch but results were not encouraging. It is essential in low-resistance circuits such as that used here to avoid transient changes in resistance and it was found necessary not to use temporary or bolted joints but to solder or weld at every joint. In addition, the current-stabilizing arrangement did not appear to be capable of operating satisfactorily when the output current was periodically interrupted.

The A_3 phase change in pure iron would be expected to occur isothermally if it could be examined under equilibrium conditions. In practice, during continuous heating or cooling, pronounced thermal lag may occur which may cause the transformation (α) to begin after

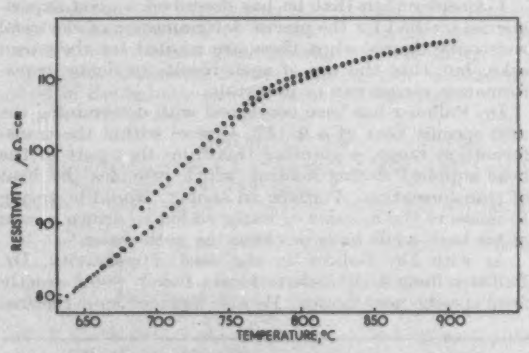


Fig. D—Resistivity/temperature curve for 0·26% C steel

* *Trans. Amer. Inst. Min. Met. Eng.*, 1940, pp. 236–244.

passing the equilibrium temperature, or (*b*) to occur over a range of temperature.

Armco iron has been considered as though it were approximately pure iron and in this context the term 'A_3 change point' has been used but owing to (*b*) the A_3 transformation has occurred over a range of temperature. Hence the beginning of the transformation has been used for locating Ac_3 and Ar_3 in Fig. 7. It is realized, however, that Armco iron is not a pure material and that the transformation may occur over a range of temperature even under equilibrium conditions. Hence deductions concerning the A_3 transformation, based on the assumption that Armco iron can be considered as pure iron, must be made with reservations.

I agree with Dr. Main that more sophisticated experimental techniques such as that applied by C. S. Smith would facilitate interpretation and, in this case, comparison between thermal curves and electrical resistivity. The difficulties met when interpreting thermal curves have been explained by Russell who showed that the results of simple techniques leave much to be desired.

My attention has been drawn to Table III of my paper in which "Resistivity at 25° C, $\times 10^{-6}\Omega$ cm" should read "Resistivity at 25° C, $\times 10^{6}\Omega$ cm". I would like to take this opportunity to include several figures illustrating results described in the text. Figure *C* gives an indication of the smoothness of the resistivity values for Armco iron and Figs. *D* and *E* show resistivity and thermal curve results.

Mr. **Heselwood**: In the United Steel Companies' laboratories we have successfully used the Smith principle for the determination of the specific heat of ores and sinters over the temperature range from room temperature to about 1400° C.

Dr. **Powell**: I am disappointed that no one has offered any comments on the maximum found in the conductivity, both electrical and thermal, at about 100° below the normal transformation range. I may have been wrong in my preconceived idea that the normalized sample would itself have the highest possible conductivity. That certainly has not proved to be the case.

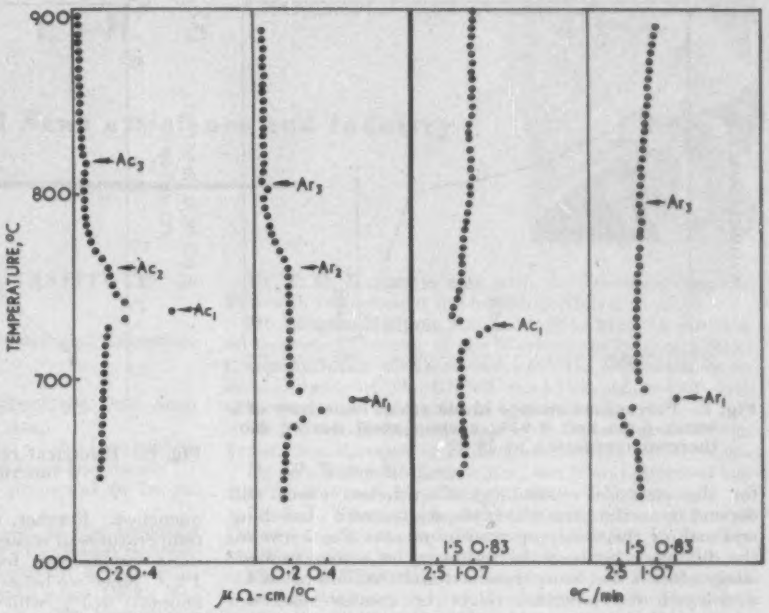


Fig. E—Differential resistivity and inverse-rate curves for 0·26% C steel

Table 1

RESISTIVITY DATA FOR PLAIN CARBON STEELS QUENCHED TO + 20° AND − 184° C

Carbon, %	Quenched to 20° C		Quenched to −184° C		Resistivity of Martensite at 23° C, μΩ cm³/cm
	Martensite, %	Resistivity at 23° C, μΩ cm³/cm	Martensite, %	Resistivity at 23° C, μΩ cm³/cm	
0·19	96·0	19·5	97·6	20·0	20·5
0·69	93·8	33·9	96·3	33·3	32·6
0·92	87·5	37·9	95·9	37·7	37·3
1·27	73·5	45·8	94·9	44·7	44·5
1·35	65·5	51·3	85·9	49·2	47·5

Recently we have been looking at some quite low-alloy steels, with carbon contents in the range 0·033–0·07%, and manganese contents of about 0·5%. Tests on four such wires again show a general tendency for a room-temperature resistivity minimum after tempering in the region of 650° C.

Similar measurements on these wires made at liquid nitrogen temperature also gave the minimum after tempering in the region of 600° C, which is well below the normal transformation of these materials.

CORRESPONDENCE

Dr. **H. W. King** and Dr. **S. G. Glover** (Birmingham University) wrote: We wish to comment on the values for the electrical resistivities of water-quenched steels given by Dr. Powell in Table I of his paper on "The Effect of Quenching on the Thermal Conductivities and Electrical Resistivities of Steel." It is well known that the tempering of martensite leads to a marked decrease in electrical resistivity. What is perhaps not so well recognized is that, in terms of the associated resistivity change, tempering appears to take place quite rapidly and to an appreciable extent at room temperature and even below. A typical example of the variation of resistivity during isothermal tempering is illustrated by Fig. *F* which refers to a 0·92% carbon steel, containing 0·28%Mn, 0·46%Si, 0·003%S, and 0·02%P, supplied by the English Steel Corporation Ltd. The results were obtained by a conventional potentiometric method using 4-in. long specimens of 0·080 in. dia. These were austenitized for 20 min at 1100° C, quenched in water, and quickly mounted in a jig carrying the electrical contacts. The jig was immersed in an oil bath and potentiometric measurements were begun immediately; the period from the moment of quenching to the completion of the first measurement never exceeded 30 s.

Under the conditions represented by Fig. *F*, it is seen that a decrease in resistivity of 0·3% has already occurred within 1 h of the first reading. After 1 day and 1 week, the percentage changes were respectively 1·2% and 2·4%. Clearly, therefore, the values obtained

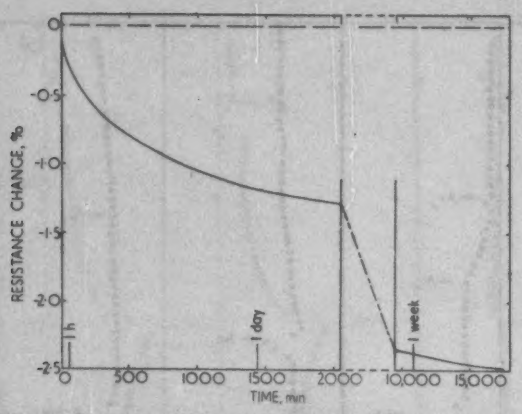


Fig. F—Percentage change in electrical resistivity of a water-quenched 0·92% carbon steel during isothermal tempering at 23° C

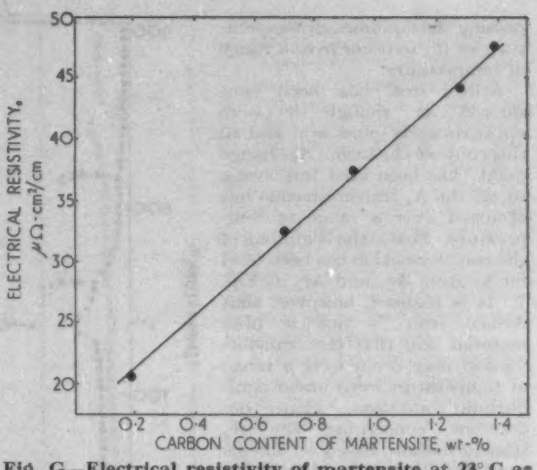


Fig. G—Electrical resistivity of martensite at 23° C as a function of carbon content

for the electrical resistivity of quenched steels will depend upon the time which elapses between quenching and making the resistivity measurements. Furthermore, the difference between the resistivity of a steel immediately after it has been quenched and that indicated by a delayed determination might be greater than the suggested limits of accuracy of Dr. Powell's results. For most of the plain carbon steels listed in Table I of his paper, the effect of delayed measurement would be, we believe, to yield a value somewhat lower than that of the freshly quenched steel.

We have made absolute measurements on a few plain carbon steels; the results are summarized in Table 1. By quenching specimens of each steel to two different temperatures (+ 20° and − 184° C) and knowing the martensite contents produced by each treatment (from saturation magnetic intensity measurements), the resistivity of the martensite phase itself was found. Figure *G* illustrates the relationship between the electrical resistivity at 23° C and carbon content for martensite. The salient results, so far as they bear upon those of Dr. Powell, are those in the third column of Table 1 for steels freshly quenched to 20° C. Over the whole range of carbon contents our values lie well above those determined by Dr. Powell for a roughly comparable range of compositions. However, the discrepancies between the two sets of results are considerably greater than can be ascribed to room-temperature tempering, even supposing that Dr. Powell determined the resistivities of the steels as long as a week after they were quenched. Further, the difference of 3° C between the temperatures of measurement used in the two investigations can account for a discrepancy of no more than 1%.* Since we believe the accuracy of our results to be about ± 0·5%, while those of Dr. Powell are probably rather better, we are forced to seek an explanation of the discrepancies in constitutional variations between the specimens of steels tested in the two investigations. Perhaps a clue lies in the fact that the biggest discrepancy is to be found between the results for the steels of highest carbon content; here our values exceed those given in the paper by about 50%. Our work has shown, not unexpectedly, that the decrease in resistivity of a martensitic steel, as it decomposes towards a ferrite–carbide structure, is the greater the higher the carbon content. This suggests that the steels tested by Dr. Powell may have contained considerable amounts of transformation products consisting of aggregates of ferrite and carbide, a circumstance not at all unlikely to result from quenching ¼-in. dia. rods, as described, in a bundle of eight.

Table 2

DECREASE IN RESISTIVITY OF 3 QUENCHED STEELS WHILST HELD AT ROOM TEMPERATURE

Steel	Dates	Time after Quenching, days	Resistivity at 20° C, μΩ cm³/cm	Decrease, %
En 8	17. 4.53	...	25·0	...
	24.11.53	7	24·7	1·3
En 19	9.11.53	...	34·25	...
	2.12.53	23	34·1	0·4
High C, Cr–Mo	12. 8.52	...	43·5	...
	13. 8.52	1	42·5	2·3
	31.10.52	80	42·2	3·0
	20. 3.53	220	42·0	3·5

In conclusion we would emphasize the importance of establishing the metallurgical conditions of specimens upon which physical measurements are to be made so that the significance of the results may be more clearly appreciated.

AUTHOR'S WRITTEN REPLY

Dr. **Powell** wrote: The occurrence of tempering at room temperature, referred to by Dr. H. W. King and Dr. S. G. Glover, does appear to be fairly general, but it would have a small effect on the room-temperature data reported for the quenched state, which were for the most part obtained within a few hours of quenching. Relevant data for the three steels dealt with in the second paper, which were obtained in the course of the original measurements are reproduced in Table 2.

The high-carbon steel will be seen to show the most pronounced rate of decrease.

As King and Glover say, the differences between their results and those of the first paper for the resistivity after quenching are much too great to be ascribed to any effect of tempering and it is agreed that the explanation must involve some difference in the actual quenching procedure.

* R. W. Powell: *J. Iron Steel Inst.*, 1946, No. 2, pp. 105p–111p.

N E W S

Announcements and News of Science and Industry

THE IRON AND STEEL INSTITUTE

Staff Changes

Mr. **A. E. Chattin,** Assistant Secretary and Librarian, retired on 31st December, 1957.

As from 1st January, 1958:

Mr. **A. Post,** Joint Assistant Secretary, has been appointed Assistant Secretary.

Mr. **M. L. Pearl** has joined the staff of the Institute as Librarian and Head of the Information Department.

Mr. **R. J. D. Harvey** has been promoted to be an Assistant Editor.

Mr. **M. Wright** has joined the staff of the Institute and is in charge of the Co-operative Translation Service.

Mr. Chattin joined the staff as Assistant Secretary in 1925 and has also served as Librarian since 1952. He will continue to give part-time service. Mr. Post joined the staff in 1946 and became Joint Assistant Secretary in 1952. Mr. Pearl has been on the staff of the British Iron and Steel Research Association since 1953; he has served as Senior Scientific Officer for the Information Section and recently as Assistant to the Head of the Development and Steel User Section. (A portrait and biography of Mr. Pearl appear on p. 8 of this issue.) Mr. Harvey joined the Editorial staff of the Institute in 1955. Mr. Wright has been on the staff of the Library of the Royal Institute of British Architects.

Special Meeting in Belgium and Luxembourg

The Institute is holding a Special Meeting in Belgium and Luxembourg from **18th to 28th June.** Preliminary details were given in the December, 1957, issue (p. 344); it is hoped to publish the full programme next month.

History of the British Iron and Steel Industry

The "History of the British Iron and Steel Industry," by Dr. H. R. Schubert was published last month by Routledge and Kegan Paul Ltd. The published price is 60*s*., but Members of the Institute may obtain copies at the special price of 50*s*. Orders should be sent to the Secretary with a remittance.

NEWS OF MEMBERS

Mr. **N. U. Bremner** has been appointed Assistant Manager of the London Section of Richard Thomas and Baldwins Ltd.

Mr. **T. Chippindale** has been appointed Fuel Oil Manager of the North Eastern Division of Shell-Mex and B.P. Ltd.

Mr. **E. G. Cutbush** is now Senior Lecturer in Metallurgy at the Battersea College of Technology.

Mr. **H. Darnell** has been appointed Chief Engineer of Workington Iron and Steel Company.

Mr. **P. R. Dixon** has left the University of Sheffield to join G.E.C. Atomic Energy Department, Materials Laboratory, Fraser and Chalmers Works, Erith.

Dr. **R. Hargreaves** has joined British Oxygen Research and Development Ltd., Morden.

Mr. **F. G. Haynes** is now with the Development and Research Department of the Mond Nickel Co., Ltd.

Mr. **Langton Highton,** J.P., has retired from the position of Managing Director of the Workington Iron and Steel Company, after 47 years' service. He will continue to be a Director of The United Steel Companies Ltd. and of its associated companies in Cumberland.

Mr. **E. von Hofsten** has taken up a position as Works Production Manager at Kohlswa Jernverks AB, Sweden.

Dr. **W. Hume-Rothery,** F.R.S., has been appointed the first Professor of Metallurgy at Oxford University.

Dr. **J. E. Hurst,** C.B.E., has retired from the position of Deputy Chairman and Managing Director of Bradley and Foster Ltd., on grounds of health.

Mr. **T. S. Kilpatrick** has been appointed Director and General Manager of the Workington Iron and Steel Company.

Mr. **W. Kita** has left the David Brown Foundries Company to become Chief Metallurgist and Steel Foundry Manager with Leopold Lazarus Ltd., Birmingham.

Mr. **L. C. Percival** has been elected President of the North London Branch of the Institute of Welding.

Mr. **G. E. Lunt** has been appointed Managing Director of Bradley and Foster Ltd.

Mr. **T. Sanderson** has succeeded Mr. D. R. Wattleworth as General Works Manager of the Workington Iron and Steel Company.

Mr. **H. H. Smith** has left Colvilles Ltd. to take up an appointment with the English Electric Co., Ltd.

Mr. **J. L. Steer** has left British Oxygen Gases Ltd. to take up the post of Physical Metallurgist with Quebec Metallurgical Industries Ltd., Columbium Products Division, Ottawa, Canada.

Mr. **A. F. Sutton** has been elected an Associate Member of the Institution of Mechanical Engineers.

Mr. **P. M. Thomas,** D.S.O., T.D., is now sole Managing Director of William Beardmore and Co., Ltd., following the resignation of Capt. Q. H. Patterson, formerly Joint Managing Director.

Mr. **D. R. Wattleworth,** O.B.E., has retired from the position of Director and General Works Manager of the Workington Iron and Steel Company, after 50 years' service.

Obituary

Mr. **John Henry Parry,** F.I.M. (*elected* 1940), Ipswich, on 13th November, 1957.

ASSOCIAÇÃO BRASILEIRA DE METAIS

The Associação Brasileira de Metais (Brazilian Society of Metals), São Paulo, has accepted an invitation to become a Kindred Society of The Iron and Steel Institute. Members of the Brazilian society are thus eligible to pay a reduced subscription to the Institute.

CONTRIBUTORS TO THE JOURNAL

M. F. Dowding, M.A., M.I.MECH.E.—Engineering Sales Manager, Davy and United Engineering Co., Ltd.

M. F. Dowding

R. W. K. Honeycombe

Michael Frederick Dowding was educated at Westminster and Magdalene College, Cambridge. After passing the Mechanical Sciences Tripos in 1940, he served with the Royal Regiment of Artillery until 1946. On leaving the Army, Mr. Dowding (who obtained his M.A. in 1945) joined Davy and United Engineering Co., Ltd., as a graduate apprentice. He was appointed Chief of Research in 1948, and two years later took up his present post as Engineering Sales Manager.

R. W. K. Honeycombe, M.SC., PH.D.—Professor of Physical Metallurgy, University of Sheffield.

Professor Honeycombe was born in Melbourne, Australia, in 1921, and educated at Geelong College and the University of Melbourne where he obtained the degree of M.Sc. in 1942. After six years as a research metallurgist in the Commonwealth Scientific and Industrial Research Organization, in 1948 he was awarded an I.C.I. Fellowship to the University of Cambridge, where he worked in the Cavendish Laboratory on the plastic deformation of metal crystals. Later he held the Royal Society Armourers' and Braziers' Research Fellowship to continue this work. In 1951 he went to the University of Sheffield as Senior Lecturer in Physical Metallurgy, and in 1955 was appointed Professor of Physical Metallurgy. His research interests in Sheffield include work on plastic deformation, fatigue, and structural studies on alloy steels.

F. W. Salt, B.SC., PH.D.—Head of Physical Chemistry Section, British Iron and Steel Research Association, Sketty Hall, Swansea.

Dr. Salt was educated at Alderman Newton's Grammar School and University College, Leicester. He obtained a B.Sc. Special (Chemistry) degree of London University in 1939; this was followed in 1942 by the degree of Ph.D. from the same university for work on hydrogen overvoltage, carried out at Leicester under Dr. A. Hickling. In 1941 Dr. Salt joined the Metallurgical Branch of the Armaments Research Department, where he carried out research on electrodeposition until 1946, when he went to the newly opened Coatings Laboratory of the British Iron and Steel Research Association at Swansea; he is now in charge of the Physical Chemistry Section of this laboratory, which is currently engaged on projects concerned with the electro-deposition of alloys, the electro-smoothing of steel strip, and the electrophoretic application of organic coatings.

F. W. Salt

J. G. N. Thomas

J. G. N. Thomas, B.SC., PH.D.—I.C.I. Fellow, University College, Swansea.

Dr. Thomas graduated in chemistry at Imperial College, London, in 1945. After two years with the Atomic Energy Project in Canada and at Harwell, he returned to Imperial College in 1947 to work with Dr. F. C. Tompkins on the kinetics of decomposition of solid barium azide, which led to the Ph.D. degree in 1950. He spent the next two years with the Colloid Science Department, Cambridge, working with Dr. J. H. Schulman on the effect of metal ions on monolayers at the air/water interface. He then joined the B.I.S.R.A. Laboratories, Swansea, leaving in 1957 to take up an I.C.I. Fellowship at University College, Swansea.

BRITISH IRON AND STEEL RESEARCH ASSOCIATION

Staff Changes

Mr. R. Mayorcas, Head of the Steelmaking Laboratory at Sheffield and latterly Deputy Head of the Steelmaking Division, has joined John Summers and Sons Ltd., Shotton. He is succeeded as Head of the Steelmaking Laboratory by Mr. G. Fenton.

Mr. J. R. Rippon of the Steelmaking Division, who was in charge of the work on continuous casting, has joined Brymbo Steel Works Ltd.

49th Steelmaking Conference

The choice of the subject " Oxygen Steelmaking " for the 49th Steelmaking Conference held at the Majestic Hotel, Harrogate, on 6th and 7th November, attracted a large attendance and gave rise to vigorous discussions. The Chairman of the Conference was Mr. R. W. Evans (Steel Company of Wales Ltd.), and Dr. J. H. Chesters (United Steel Companies Ltd.) was the Vice-Chairman.

On the first day two papers were presented. One, by Mr. H. F. Padbury (Richard Thomas and Baldwins Ltd.) on " Modern Converter Steelmaking Processes," described the continental developments of recent years with regard to the use of oxygen-enriched air, oxygen–steam and oxygen–carbon-dioxide blasts for bottom-blown converters, and the oxygen top-blowing process. The other paper, " Oxygen Steelmaking Research at the Inland Steel Company," was presented by Mr. J. W. Halley (Inland Steel Company, Ind., U.S.A.). He described how research at the Inland Steel Company had demonstrated that charges of over 90% hot metal of up to 1·0% phosphorus can be refined to steel at production rates of over 40 tons/h by lancing with oxygen in an open-hearth furnace.

On the second day a paper entitled " Some Remarks on the Kaldo and Rotor Steelmaking Processes " was presented by Dr. A. H. Leckie (Iron and Steel Board), who based his talk on visits he had made to see these processes in operation and on discussions with the manufacturers of Kaldo and Rotor plants. The final paper of the Conference was presented by Mr. R. A. Granville (B.I.S.R.A.) on " The Fume Aspect of Oxygen Steelmaking Processes: Some Thoughts on Our Present Knowledge." Mr. Granville introduced his subject by a film made available by Dorman Long (Steel) Ltd., which showed the marked reduction in the fume observed at the chimney when 50% by weight of the oxygen used in the oxygen desiliconizing of iron is replaced by steam.

25th Blast Furnace Conference

The 25th Blast Furnace Conference was held at Harrogate on 17th and 18th October. Dr. T. P. Colclough, C.B.E. (British Iron and Steel Federation) took the Chair, and Mr. E. M. Summers (Stanton Ironworks Co., Ltd.) was Vice-Chairman.

The first group of papers, referring to "Present-day Engineering Limitations and Some Solutions" were given by Mr. K. C. Sharp (Steel Company of Wales Ltd.), Mr. J. Lockerbie (Consett Iron Co., Ltd.), Mr. C. P. Gunstone (Stewarts and Lloyds, Ltd.), and Mr. D. Rist (Dorman Long (Steel) Ltd.). Recent engineering developments were reviewed and, with the increased size of operating units and productivity, an indication was given of further problems yet to be solved. To achieve the higher outputs now required, views were expressed on necessary improvements in furnace and ancillary equipment. A variety of methods used to simplify maintenance and to reduce downtime were described. The provision of adequate and up-to-date tools for carrying out repairs was considered to be of importance.

By special invitation, Mr. J. M. Stapleton (United States Steel Corporation) and Mr. J. H. Strassburger (National Steel Corporation) attended the Conference, and each presented a paper describing various engineering aspects of operation in the U.S.A. at the second session. The papers also gave a general review of contemporary U.S. practice and many interesting features of operation were described.

For the third session the Chair was taken by Mr. G. H. Johnson (Kettering Iron and Coal Co., Ltd.). A paper was given by Mr. H. M. Richardson (British Ceramic Research Association) on blast-furnace stack refractories. Evidence on the examination of blown-out furnaces was considered to emphasize stack lining limitations. Reference was then made to the production aims drawn up by the Blast Furnace Refractories Joint Committee as a target for improved refractories.

Engineering research and future plant design were the subjects chosen for the concluding session. Papers were presented by Mr. R. H. Siddons (United Steel Companies, Ltd.), Commander J. I. T. Green (B.I.S.R.A.), and Major W. R. Brown (Ashmore, Benson, Pease and Co., Ltd.). These dealt with immediate engineering problems, current engineering research projects, and trends in the design of furnace plant and equipment.

INSTITUTE OF METALS

Clustering and Precipitation in Metals

A lecture on "The Mechanism of Clustering and Precipitation in Metals" will be given on Wednesday, 15th January, by Dr. David Turnbull, Manager of the Chemical Metallurgy Section of the Research Laboratory of The General Electric Company, Schenectady, N.Y. The lecture, which is being arranged by the Metal Physics Committee of the Institute, will take place at the Institute's Headquarters, 17 Belgrave Square, London, S.W.1, at 6.30 p.m. The meeting is open to visitors, without tickets.

BRITISH NUCLEAR ENERGY CONFERENCE

Admission of New Member

At a meeting of the Board of the B.N.E.C. held on 9th October, The Institute of Fuel, covering the interests of fuel technology, was admitted to membership.

Binding of Journal

Binding facilities for Vol. II (1957) are available at the following charges, which include postage:

Binding case only, 12*s.* 6*d.*

Supply of case and binding, £1 5*s.* 0*d.*

Orders for binding cases or copies of the *Journal* with index should be sent, with the appropriate remittance, to William Clowes and Sons, Ltd. (Publishing Dept.), Little New Street, London, E.C.4.

EDUCATION

Postgraduate Course on Fatigue

A course of lectures on "Engineering and Metallurgical Aspects of Fatigue" is being given at Battersea College of Technology on Tuesday evenings from 7 to 9 p.m., beginning on 14th January. The fee for the course of ten lectures is £1 0*s.* 0*d.* Full details and enrolment forms may be obtained from the Secretary (Fatigue Lectures), Battersea College of Technology, Battersea Park Road, London, S.W.11.

Chemical and Metallurgical Thermodynamics

Dr. O. Kubaschewski, of the National Physical Laboratory, is giving a course of lectures on "Applied Thermodynamics for Metallurgists and Chemists" at Battersea College of Technology, commencing 8th January at 7 p.m. The course has been arranged for metallurgists and chemists desirous of obtaining an insight into the value of the thermodynamic approach to metallurgical and chemical processes. The purpose of the course is to show how thermodynamics can be applied to practical problems. Applications for admission to the course, the fee for which is £1 0*s.* 0*d.*, should be made to the Secretary (A/T Course), Battersea College of Technology, Battersea Park Road, London, S.W.11.

Joint Committee for National Certificates in Metallurgy

The Committee reports the following results of examinations held in 1957, and comparative figures:

Ordinary National Certificate

Year	Technical Colleges	Entered	Total Certificates Awarded	With Distinction	With Prize Award
1946	4	28	23	4	7
1948	15	123	74	12	16
1950	20	281	142	23	26
1952	28	334	186	22	31
1954	37	522	258	25	39
1956	37	571	296	31	42
1957	**38**	**600**	**288**	**36**	**47**

Entered since 1946: 4010 Certificates awarded: 2040

Higher National Certificate

1946	...	...	...	...	...
1948	8	38	22	1	2
1950	11	62	42	8	10
1952	16	132	120	16	22
1954	18	173	144	22	31
1956	23	247	205	23	27
1957	**24**	**275**	**222**	**26**	**32**

Entered since 1946: 1456 Certificates awarded: 1140

Endorsement Subjects—Ordinary National Certificate

1955	5	39	27	1	1
1956	6	56	23	7	7
1957	**8**	**104**	**43**	**2**	**2**

Endorsement Subjects—Higher National Certificate

1955	11	70	66	7	7
1956	12	102	89	8	8
1957	**13**	**130**	**93**	**3**	**3**

Assessed Examination in Mathematics S.2

Year	Technical Colleges	Entered	Passed
1952	5	77	44
1954	22	321	220
1956	28	570	391
1957	**37**	**687**	**431**

Of the successful candidates for the H.N.C. in Metallurgy, 16 attained the Exemption Standard of the Institution of Metallurgists and qualified for exemption from the Licentiateship examinations in three or more subjects, bringing the total for the period 1952–1957 to 108.

Modern Metallographic Techniques

A course of six lectures and four practical periods on "Modern Metallographic Techniques" is being held at Northampton College of Advanced Technology, St. John Street, London, E.C.1, on Thursday evenings at 6.30 p.m., beginning on 16th January. The fee for the whole course is £1 0*s*. 0*d*. and for the lectures alone 10*s*. 0*d*. Enrolment may be effected by personal attendance at the College or by post, giving name, address, qualifications, and name of employer and enclosing the fee and a stamped addressed envelope.

NEWS OF SCIENCE AND INDUSTRY

"Steelplant Refractories"

A second edition of "Steelplant Refractories," by Dr. J. H. Chesters, has recently been published by The United Steel Companies Ltd. A review appears on p. 94 of this issue.

Kaldo Process for the U.K.

The Kaldo steelmaking process, developed by Professor Bo Kalling at Domnarvet in Sweden, is now available in the U.K. An agreement between BAMAG of Germany and Head, Wrightson Iron and Steel Works Engineering Ltd. will enable the latter to offer designs and complete engineering services to British companies.

Automatic Production Lines at Timken

British Timken Ltd. has recently put into operation at its Duston works a fully automatic production line for tapered roller bearings of 1½–3 in. o.d. The new building has three main departments—an automatic machine shop, a hardening (heat-treatment) shop, and a grinding and assembly shop. Much of the equipment was designed by the Timken engineers and production personnel, and incorporates many interesting features.

Continuous Casting at Low Moor

Some details are now available of the continuous casting plant at Low Moor Alloy Steelworks Ltd., which has been operating successfully for some time.

The Low Moor machine is about 50 ft high, of which about 35 ft is below ground level. It is fed from a standard steel ladle with metal melted in electric arc furnaces. The steel, which is at a controlled temperature determined with the aid of an immersion thermocouple, is poured into a tundish with one or more refractory stoppers controlling the metal flow into the water-cooled mould or moulds. At the start of the operation there is a dummy plug in the bottom of each mould; this is withdrawn at a predetermined suitable speed and is followed by the partially frozen steel bar. The steel section, which at this stage is still liquid internally, follows the plug down through the machine past water-cooling units, guided by rolls; the steel is "pinched" and eventually, after further guiding, the sound solid bar is cut into the desired lengths and is mechanically hoisted back to floor level. Specially adapted electronic equipment is used at various control points.

The existing machine produces squares and rounds of 3½–5½ in., which can be manipulated in single- or twin-strand moulds. Slabs in special grades can also be made in large sizes and other moulds with a different cross-section. The steel is sound both internally and on the surface and has a well defined and evenly distributed grain structure.

Translation of Russian Journals

The board of governors of *Acta Metallurgica* have announced that they will begin the publication this month of English-language translations of two Russian metallurgical publications—*The Physics of Metals and Metallography* and *The Journal of Abstracts—Metallurgy*. The first issues to be translated will be those of January, 1957; it is hoped to speed up production so that the English editions will be available shortly after the Russian original appears.

The subscriptions to the two journals will be $30 per year for *The Physics of Metals and Metallography* and $20 per year for the abstract journal, but members of The Iron and Steel Institute, which is a co-operating society, may obtain copies at half these rates.

"Men, Steel and Technical Change"

The Department of Scientific and Industrial Research has recently started publishing a new series of booklets under the general title of "Problems of Progress in Industry." The first in the series, entitled "Men, Steel and Technical Change," is based on an intensive study of technical progress in a large British steelworks. It traces the relationship between technical and social changes, especially during the past two decades. It deals first with technical changes and with trends in the size and composition of the labour force, then reviews the problems of management and relations with trade unions, and ends by studying the attitudes of employees to change.

The booklet is obtainable from H.M.S.O., price 2*s*. 0*d*.

Associazione Italiana di Metallurgia

The next National Convention of the A.I.M. is being held in Turin in the second half of September, 1958, under the auspices of the Piedmont section.

Industrial Publications Received

Hadfields Ltd., East Hecla Works, Sheffield, have published an illustrated catalogue on "Crushing Rolls."

"Draughtless Aspirating Air Diffusers" is the title of the latest brochure published by Anemostat (Scotland) Ltd., 220 West Regent Street, Glasgow.

Leaflet No. V54 of the Incandescent Heat Co., Ltd., Cornwall Road, Smethwick, Birmingham, deals with the "Equiverse" heating system.

A brochure on forging manipulators, furnace chargers, and handlers has been issued by the Wellman Smith Owen Engineering Corporation, Ltd., Wilton Road, London, S.W.1.

Changes of Title and Address

Shandon Automation and Electronics Ltd., is now known as Shandon Electronics Ltd., and will function in future purely as a selling organization. Its manufacturing division has been transferred to E. R. Shandon and Co., Ltd., who are now at 65 Southern Row, Kensal Road, London, W.10 (LADbroke 6491–3).

The U.K. agency for Demag A.G. and Demag-Electrometallurgie G.m.b.H. has been transferred to Mr. Boris Ryman, 56 Curzon Street, London, W.1 (GROsvenor 4121).

Wm. Park and Co. (Forgemasters) Ltd. has been converted into a holding company; a new company, to be known as Parks Forge Ltd., has taken over its trading assets, trade, and connection. The address of both companies remains Clarington Forge, Wigan.

CORRIGENDA

In Table VI of the paper by Taylor, Lonie, and Hay, entitled "A Study of the Tuyere Combustion Zone", which appeared on pp. 330–341 of the December, 1957, issue of the *Journal*, the second column from the left was omitted. The letters *A–L* should be inserted reading downwards: *A–H* refer to Clyde coke and *I–L* to Consett Coke. A correction should also be made on p. 336, where, in line 15 of the left-hand column, "B1" should read "B2."

DIARY

6th Jan.—Cleveland Institution of Engineers—"20th Century Industrial Locomotives," by T. A. Hill—Cleveland Scientific and Technical Institution, 6.30 p.m.

7th Jan.—East Midlands Metallurgical Society—"The Oil Industry", by J. Collins—Nottingham and District Technical College, Shakespeare Street, Nottingham, 7.30 p.m.

7th Jan.—Sheffield Metallurgical Association—Annual General Meeting of Methods of Analysis Group—B.I.S.R.A., Hoyle Street, Sheffield, 7 p.m.

8th Jan.—Newport and District Metallurgical Society—"Nuclear Power at Berkeley," by M. Mycock—Whitehead Institute, Cardiff Road, Newport, 7 p.m.

9th Jan.—Ebbw Vale Metallurgical Society—Symposium on Continuous Galvanizing—Richard Thomas and Baldwins Lecture Rooms, 7.15 p.m.

9th Jan.—Leeds Metallurgical Society—"Corrosion Problems and Water Treatment in Power Stations," by R. W. Wolforth—Chemistry Wing, The University, Leeds, 7.15 p.m.

13th Jan.—Lincolnshire Iron and Steel Institute—"The European Coal and Steel Community—How It Works," by Dr. H. G. Vorwerk—North Lindsey Technical College, Scunthorpe, 7.30 p.m.

14th Jan.—Institute of Metals (South Wales Local Section)—"Electron Microscopy," by Dr. J. W. Menter—Department of Metallurgy, University College, Swansea, 6.30 p.m.

14th Jan.—Sheffield Metallurgical Association—Annual General Meeting of Refractories Group—B.I.S.R.A., Hoyle Street, Sheffield, 7 p.m.

15th Jan.—Institute of Metals—"The Mechanism of Clustering and Precipitation in Metals, by Dr. D. Turnbull—17 Belgrave Square, London, S.W.1.

15th Jan.—Manchester Metallurgical Society—Film evening—Metropolitan-Vickers Electrical Ltd., Trafford Park, Manchester, 7 p.m.

15th Jan.—North Wales Metallurgical Society—"Sounding Brass," by F. C. Draper—Flintshire Technical College, Connah's Quay, near Chester, 7.15 p.m.

15th Jan.—Society of Chemical Industry (Corrosion Group)—"Stress Corrosion Cracking," by Dr. T. P. Hoar and Dr. J. G. Hines—14 Belgrave Square, London, S.W.1, 6.30 p.m.

15th Jan.—Swansea and District Metallurgical Society—"Recent Developments in Iron and Steel Works Practice," by W. F. Cartwright—Central Library, Swansea, 7 p.m.

16th Jan.—Institute of British Foundrymen (London Branch)—Dinner-Dance—Connaught Rooms, London, W.C.2.

16th Jan.—Staffordshire Iron and Steel Institute—"Alternative Methods of Making Iron and Steel," by Dr. A. G. Robiette—Station Hotel, Dudley, 7.30 p.m.

21st Jan.—Institution of Chemical Engineers (in conjunction with British Nuclear Energy Conference)—Symposium on Nuclear Energy—Church House, London, S.W.1.

21st Jan.—Sheffield Metallurgical Association—Annual General Meeting—B.I.S.R.A., Hoyle Street, Sheffield, 7 p.m.

22nd Jan.—Institute of Welding—"Welding of Austenitic Steels," by M. E. Pool—Cleveland Scientific and Technical Institution, Middlesbrough, 7.30 p.m.

23rd Jan.—Institute of Metals (Birmingham Local Section)—"Electric Furnace Developments," by P. F. Hancock—Birmingham Exchange and Engineering Centre, Stephenson Place, Birmingham, 6.30 p.m.

24th Jan.—North East Metallurgical Society—"Some Views on the Use of Oxygen in Steelmaking," by T. F. Pearson—Cleveland Scientific and Technical Institution, Middlesbrough, 7.15 p.m.

28th Jan.—Sheffield Metallurgical Association—"The Production of Continuous Stainless Steel Sheet," by J. A. Campbell—B.I.S.R.A., Hoyle Street, Sheffield, 7 p.m.

29th Jan.—Manchester Metallurgical Society—"The Behaviour of Metals at High Temperatures," by Dr. N. P. Allen, F.R.S.—Central Library, Manchester, 6.30 p.m.

CO-OPERATIVE TRANSLATION SERVICE

The following translations are now available, in addition to those given on p. 348 of the December, 1957, issue of the *Journal*:

587. Bandel and Gravenhorst: "Behaviour of High-temperature Steels during Creep Testing at Temperatures of 500–700° C. Part II—Evaluation Methods." *Arch. Eisenhüttenwesen*, 1957, vol. 28, May/June, pp. 253–258. (£2 10*s*. 0*d*.)

593. Jahn: "Behaviour of High-Temperature Steels during Creep Testing at Temperatures of 500–700° C: Part III—Results of Creep Tests on Ferritic Tube Steels." *Arch. Eisenhüttenwesen*, 1957, vol. 28, May/June, pp. 259–267. (£2 15*s*. 0*d*.)

631. Tselikov and Sonin: "Coiling and Uncoiling Hot Rolled Plates of up to 12 mm thickness." *Stal*, 1957, No. 4, p. 374. (£2 0*s*. 0*d*.)

659. Seul and Billigmann: "Experiences in the Rolling and Re-rolling of Wide Strip in Multiple-stand Cold Rolling Mills." *Stahl u. Eisen*, 1955, vol. 75, Feb. 10th, pp. 144–162, disc. 1955, June 16th, pp. 779–784; Dec. 15th, pp. 1710–1720. (£10 0*s*. 0*d*.)

660. Spiller and Funke: "Investigations on a 4-high Reversing Mill Stand Rolling Cold Strip for Tinplate. Part I—Measurements to Determine the Power and Work Required and the Degree of Utilization; Part II—Effect of Rolling Force, Rolling Speed, Strip Tension, and Amount of Lubrications Used on the Trueness to Dimensions of Cold-rolled Strip." *Stahl u. Eisen*, 1957, June 27th, pp. 867–881. (£8 10*s*. 0*d*.)

673. Reiner: "Behaviour of High-temperature Steels during Creep Testing at Temperatures of 500–700° C: Part I—Experimental Installations and Procedures." *Arch. Eisenhüttenwesen*, 1957, vol. 28, May/June, pp. 247–252. (£2 15*s*. 0*d*.)

684. Vonneman: "New Methods of Hot Cooling." *Stahl u. Eisen*, 1957, vol. 77, Aug. 22nd, pp. 1126–1134. (£4 10*s*. 0*d*.)

693. Hansen and Spitzer: "The Ventilation of Workshops in Iron and Steel Plants." *Stahl u. Eisen*, 1957, vol. 77, No. 4, Feb. 21st, pp. 204–215. (£7 10*s*. 0*d*.)

698. Rys: "High-temperature Microscopy." *Neue Hütte*, 1957, pp. 489–497. (£3 5*s*. 0*d*.)

702. Naeser: "An Improved Colour-Brightness Pyrometer and its Application." *Stahl u. Eisen*, 1956, vol. 76, July 26th, pp. 968–970. (£1 10*s*. 0*d*.)

708. Rättig: "The Effluent Problem in Pickling Plants and its Solution." *Bloch*, 1955, No. 3, March. (£1 10*s*. 0*d*.)

710. Springorum *et al.*: "Experiences and New Findings in Refining of Basic Bessemer Pig Iron by Blowing with Pure Oxygen." *Stahl u. Eisen*, 1957, vol. 77, No. 19, Sept. 19th, pp. 1284–1296. (£5 10*s*. 0*d*.)

718. Onoprienko and Starshinov: "Operation of a Blast-furnace with a Top Gas Pressure of up to 1·1 Atmospheres." *Stal*, 1957, Sept., pp. 772–778. (£4 0*s*. 0*d*.)

720. Bjerkerud: "Determination of Carbon and Sulphur in the Same Sample of Steel." *Jernkontorets Ann.*, 1955, vol. 139, pp. 847–852. (£1 5*s*. 0*d*.)

725. Nikolaichik and Nikolaichik: "Calorising of Cast Iron Ingot Moulds." *Stal*, 1957, No. 6, p. 571. (£1 15*s*. 0*d*.)

747. Thum and Richard: "100,000 hr. Creep Tests at 500° C on Various Types of Steel." *Arch. Eisenhüttenwesen*, 1957, vol. 28, May/June, pp. 325–337. (£5 0*s*. 0*d*.)

748. Krisch and Wepner: "On the Conversion of Creep Values to Other Temperatures." *Arch. Eisenhüttenwesen*, 1957, vol. 28, May/June, pp. 339–344. (£3 5*s*. 0*d*.)

762. Harada *et al.*: "Hot Rolling with Idler Roll Stands in a Continuous Wire Mill." *Tetsu-to-Hagané*, 1956, vol. 42, Sept., pp. 936–938. (£3 0*s*. 0*d*.)

766. Graue and Zöhler: "The Rapid Determination of Calcium and Magnesium Contents in Ores and Slags." Contribution from the Technical Materials Testing Establishment of Hüttenwerk Phoenix A.G., Duisberg-Ruhrort. (£1 5*s*. 0*d*.)

783. Schilcher: "The Evaporative Cooling of Blast-Furnace Tuyères." *Stahl u. Eisen*, 1956, vol. 76, No. 19, pp. 1229–1231. (£1 10*s*. 0*d*.)

789. Cai *et al.*: "The Training of Railway Personnel in Steelworks." Paper presented at the International Transport Conference; London, September 1957. (From Italian). (£7 0*s*. 0*d*.)

ABSTRACTS OF CURRENT LITERATURE AND BOOK NOTICES

Iron and Steel Manufacture and Related Subjects

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ABBREVIATIONS AND LIST OF PERIODICALS EXAMINED BY THE ABSTRACTING SERVICE

Note.—Abbreviations are being shortened to the forms here shown as quickly as possible. Abstracts already in print have the titles published last January.

Abhandlungen der **Braunschweigischen** wissenschaftlichen **Gesellschaft** (Brunswick)
Academia Republicii Populare **Romine**, Studii si Cercetari de **Metalurgie** (Bucharest)
Acciaio e **Costruzioni Metalliche** (Milan)
Acciaio Inossidabile (Milan)
Acero y **Energía** (Barcelona)
Acier-Stahl-Steel (Brussels)
Aciers Fins et **Spéciaux** Francais (Paris)
Acta Crystallographica (London)
Acta Metallurgica (Toronto)
Acta Physica Polonica (Warsaw)
Acta Polytechnica (Copenhagen and Stockholm)
Acta Technica (Budapest)
Admiralty Advisory Committee on **Structural Steel** (London)
Brittle Fracture Research in the U.K. Reports
Advancement of **Science** (London)
Advances in **Physics** (London)
Aeroplane (London)
Aircraft Engineering (London)
Aircraft Production (London)
Ajour Teknisk Informasjon (Oslo)
Alloy Castings Bulletin (New York)
Alloy Metals Review (Widnes)
Alluminio (Milan)
Aluminium (Düsseldorf)
Aluminium Development Association, Information Bulletin (London)
American Ceramic Society Bulletin (Columbus, Ohio)
American Foundrymen's Society, Preprint (Chicago)
American Gas Association Monthly (New York)
American Institute of **Mining** and **Metallurgical Engineers** (New York)
Blast Furnace, Coke Oven & Raw Materials **Committee, Proceedings**
Electric Furnace Steel Conference Proceedings
Proceedings National **Open-Hearth Committee**
Proceedings **Symposia** Series
American Iron and Steel Institute (New York)
Annual Statistical Report
Contributions to the **Metallurgy** of **Steel**
Steel Products Manual
American Journal of **Physics** (New York)
American Journal of **Science** (New Haven, Conn.)
American Society for **Metals** (Cleveland, Ohio)
Preprint
American Society for **Testing Materials** (Philadelphia)
Bulletin
Preprint
Special Technical Publication
Anais da **Academia Brasileira** de **Ciencias** (Rio de Janeiro)
Anais Associacao Brasileira de **Quimica** (Sao Paulo)
Anales de la **Asociacion Quimica Argentina** (Buenos Aires)
Anales de la **Real Sociedad Española** de **Fisica** y **Quimica** (Madrid)
Anales de **Mecanica** y **Electricidad** (Madrid)
Analyst (London)
Analytica Chimica Acta (New York and Amsterdam)
Analytical Chemistry (Washington)
Annales des **Mines** (Paris)
Annales de la **Société Scientifique** de **Bruxelles** (Brussels)
Annual Report of the **Smithsonian Institution** (Washington)
Annual Review of **Physical Chemistry** (Stanford, California)
Anvil (Sheffield)
Applied Mechanics Reviews (New York)
Applied Research Laboratories, Reports (Glendale, Calif.)
Applied Scientific Research (The Hague)
Archiv für das **Eisenhüttenwesen** (Düsseldorf)
Archiwum Elektrotechniki (Warsaw)
Archiwum Hutnictwa (Warsaw)
Arkiv för **Kemi** (Stockholm)
Arkiv för **Mineralogi** och **Geologi** (Stockholm)
Arts et Manufactures (Paris)
Atomics and **Nuclear Energy** (London)
Atti della **Accademia** Nazionale dei **Lincei**, Classe di Scienze Fisiche, Matematiche e Naturali (Rome)
Memorie
Rendiconti
Australasian Engineer (Sydney)
Australian Journal of **Applied Science** (Melbourne)
Australian Journal of **Chemistry** (Melbourne)
Australian Journal of **Physics** (Melbourne)
Australian Machinery and **Production Engineering** (Sydney)
Automation in **Industry** (London)
Automation Progress (London)
Automobile Engineer (London)
Avtomaticheskaya Svarka (Kiev)
Avtomatika (Kiev)

B.C. Professional Engineer (Vancouver)
B.H.P. Review (Melbourne)
B.H.P. Technical Bulletin (Melbourne)
Battelle Technical Review (Columbus, Ohio)
Beama Journal (London)
Bell Laboratories Record (New York)
Bell System Technical Journal (New York)

Bell Telephone Magazine (New York)
Bell Telephone System Technical Publication (New York)
Berg- und Hüttenmännische Monatshefte (Vienna)
Bibliographical Bulletin of Welding (Paris)
Blad för Bergshandteringens Vänner (Stockholm)
Blast Furnace and Steel Plant (Pittsburgh)
Board of Trade Journal (London)
Boletim da Associação Brasileira de Metais (São Paulo)
Boletim da Sociedade Geológica de Portugal (Oporto)
Boletin Minero e Industrial (Bilbao)
Brennstoff–Warme–Kraft (Düsseldorf)
British Cast Iron Research Association, Journal of Research and Development (Birmingham)
British Coal Utilisation Research Association, Monthly Bulletin (London)
British Coke Research Association, Technical Papers (London)
British Constructional Steelworks Association (London)
Publications
British Dental Journal (London)
British Electrical and Allied Industries Research Association, Reports (London)
British Engine Boiler and Electrical Insurance Co. Ltd. (Manchester)
Technical Report
British Engineering (London)
British Foundryman (Manchester)
British Iron and Steel Research Association, Reports (London)
British Journal of Applied Physics (London)
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The Iron Mines of Chile. F. Benitez. (*Eng. Min. J.*, 1957, **158**, July, 90–93). A review of deposits with maps and analyses.

Kauaeranga Sulphide Deposit, Thames [N.Z.]. D. Kear. (*New Zealand J. Sci. Techn.*, 1957, **38**, Section B, May, 483–495). A survey of a pyrites deposit is presented.

Titanomagnetites from a Differentiated Teschenite Sill. J. F. G. Wilkinson. (*Mineralogical Mag.*, 1957, **31**, June, 443–454). The role of titanomagnetites in basaltic magma iron enrichment is discussed.

A Survey of the Iron Ore Industry in Canada During 1956. T. H. Janes. (*Canad. Mines Techn. Surveys*, 1957, M.R.22, May 3, pp. 83). Geographical and statistical, with a survey of minerals and a list of the companies engaged with annotations.

ORES—MINING AND TREATMENT

The Rise of Chemical Metallurgy. (*Eng. Min. J.*, 1957, **158**, mid-June, 118–123). Illustrated with flowsheets, Ni, Co, V and U extraction plants are shown, with the limonite grinding circuit of Nickel Processing Corp.

Pelletizing of Coarse-grained Iron Ore Fines and Metallic Pulps. L. Visnyovszky and T. Holló. (*Kohászati Lapok*, 1955, **10**, May 201–210). Hungarian small-scale experiments have shown the possibility of using coarse grained iron ore fines of max. dia. 10 mm for pelletizing, mixed with manganese or alumina pulps. Pressure is necessary for compacting the mixture. Burning the balls may be carried out in rotary or in pit furnaces.—P. K.

The Significance of Iron Coke in Ferrous Metallurgy. E. Haidegger. (*Kohászati Lapok*, 1956, **11**, March, 93–96). The production of iron coke from gas coal and iron ore, its characteristics and use in the blast furnace, low shaft furnace and Thyssen gas producers are reviewed.—P. K.

Problems of Sinter Production. L. I. Kharash, M. I. Shinyakov and S. I. Èliasberg. (*Stal'*, 1957, (2), 106–114). [In Russian]. After a review of developments in the U.S.S.R. and abroad leading to the use of larger sintering machines and a discussion of defects of existing machines, details are given of the project for a machine with 200 in² sintering area. The distinctive process features of the project are: the use of a separate bedding system with a 96-h operational capacity for each machine; a two-stage pelletization of the charge, fuel and a binder being added at the second stage; double layer charging of the mix on to the strand; the preheating of the charge over the first two wind boxes by gas at 300–400°C from the twentieth wind box, the first of the four used for cooling on the strand; the final cooling of the crushed cake on a special straight vibrating cooler served by 5 fans rated at 1500 m³/min each. The buildings are to be in pre-fabricated reinforced concrete and of the advantageous single-storey pavilion type. Improved materials conveying and gas cleaning systems are to be used, and the layout is designed to reduce the total drop of pellets on to the strand to 1·15 m, with minimal conveying distances, prevention of dust nuisance and easy maintenance. The new equipment required for the large projected machines (36 m² for laying the charge, 24 m² for charge pre-heating 200 m² for sintering and 60 m² for cooling) is listed and the economics of plant operation are compared for various sizes of machine. The 200 m² machines are shown to be advantageous and they are recommended for plants of equal or greater sintering areas.

Improvement in the Size Composition of Krivoi-Rog Ores for Sintering. M. I. Kostyuk, S. K. Grebnev, A. A. Aksenov, P. E. Ostapenko and M. A. Simacheva. (*Stal'*, 1957, (2), 114–118). [In Russian]. Better size composition of Krivoi-Rog ore received at sintering plants has been obtained by using electrical heating to raise the temperature of screens to 50°–60°C.—S. K.

Ferro-Coke and Ore-Coal Briquettes. M. S. Kurchatov. (*Stal'*, 1957, (2), 103–105). [In Russian]. From a consideration of information in the literature on the production and use of ferro-coke and his own laboratory experiments on ore-coal briquettes with various carbon contents the author concludes that it is better to smelt briquettes. The briquettes should contain enough carbon to complete their reduction. The appearance of briquettes prepared from magnetite and coking or brown coal is illustrated for various degrees of reduction of the ore and fuel contents, and the corresponding figures for the gas-phase composition are shown. The manufacture and production costs of briquettes are not considered.

Sinter Cooling: An Essential Feature of Modern Sintering Plants. G. Brandes and H. Wendeborn. (*Stahl u. Eisen*, 1957, **77**, May 30, 693–701). Automatic transport of sinter involves the use of conveyor belts containing rubber, i.e. the sinter must be cooled for transport. The author describes various types of cooling devices in which air is sucked through the hot sinter.—T. G.

Sinter-plant Assessment Trials at John Summers and Sons Ltd., Shotton. H. Bates, G. C. Carter, and D. F. Ball. (*J. Iron Steel Inst.*, 1958, **188**, Jan., 45–54). [This issue].

Refractory Linings for Rotary Agglomeration Furnaces of the Krupp-Renn Type. E. Viktora and V. Závěský. (*Hutnické Listy*, 1957, **12**, (5), 417–423). [In Czech]. A detailed analysis was made of the attack of the melt on acid fire brick used as lining. It is shown that an appreciable increase in the life of the lining is obtainable by decreasing the porosity of the bricks. Porosity should be below 10%; the ideal state would be nul porosity. Some hints are given concerning the design of the furnaces, with a view to a decrease in the wear and increase in the durability of the linings in regions of severest attack.—P. F.

The Use of Natural Gas for the Reduction of Iron Ores. J. Raffin. (*Ann. Mines.*, 1957, June, 345–352). The Höganas, Wiberg, Krupp-Renn, H-iron and ONIA processes are outlined and costs and future prospects are discussed.

Taconite Pellets—Problems of Car loading, Stockpiling and Loading Vessels. L. O. Millard. (*Iron Steel Eng.*, 1957, **34**, June, 179–186). This article describes the pelletizing stocking and handling installations of the Erie Mining Co. which will be the largest in the world.—M. D. J. B.

Thermal Analysis of Iron Ores with the Habicht Instrument. B. Vecsey. (*Kohászati Lapok*, 1955, **10**, April, 149–151). The author describes the construction and use of the Habicht instrument and gives an example of its use in determining the composition of a Hungarian bauxite from the results of chemical and thermal analysis.—P. K.

FUEL—PREPARATION, PROPERTIES, AND USES

Coalfields of the Republic of Korea. Part 2. J. A. Reinemund, E. M. Baldwin and K. G. Brill jun. (*U.S. Geol. Survey Bull.*, 1041-C, D, E, 1957, pp. 99).

Central Coal Preparation Plant in India. (*Min. J.*, 1957, **249**, Aug. 16, 196–197). An account of a Tata Iron and Steel Co. plant at Jamadoba is given.

Froth Flotation of Low-rank Coal. II. A Statistical Investigation of Six Factors Influencing Froth Flotation. G. F. Eveson, S. G. Ward and F. Worthington. (*J. Inst. Fuel*, 1957, **30**, June, 298–309). Experiments are reported which show the influence of each of the following variables on the froth flotation of a low rank bituminous coal in a laboratory cell: size range of feed solids; pulp density; pH value of the pulp; collector concentration; frother concentration; conditioning time. Conclusions include:—concentration of frother in the pulp is the most important factor; conditioning time should be as short as possible.

The Reduction of Coal Samples taken for the Determination of Total Moisture Content. A. Crawford and D. H. Ward. (*J. Inst. Fuel*, 1957, **30**, June, 314–321). The work described in this paper deals with the treatment of the moisture sample after its removal from the gross sample. It demonstrates the precautions which should be taken in the choice of mill for crushing, and shows the stage at which air drying is necessary for different types of coal samples.—D. L. C. P.

New Coking Plant: Simon-Carves Installation at Dorman Long, South Bank. (*Iron Steel*, 1957, **30**, July, 361–362). The new Simon-Carves coking plant at South Bank, Middlesbrough, provides metallurgical coke for the new Clay Lane blast furnaces of Dorman Long (Steel) Ltd. It comprises 150 ovens with a weekly throughput of 25,000 tons of coal. Brief details are given of the coal-handling plant, the coke ovens, and the by-product plant.—G. F.

Factors and Limitations Involved in the Use of Industrial Gases for Underfiring Coke Ovens. L. G. Tucker jun. (*Blast Furn. Steel Plant*, 1957, **45**, May, 483–488; June, 614–617). Factors influencing the selection of gases for underfiring coke ovens instead of coke oven gas are considered. Examples of the successful use of a wide variety of gases for underfiring are given.—B. O. B.

The Shatter Strength of Cokes from High-Volatile Coals: Use of Plastometer Measurements on Blends for Test-oven Experiments. D. W. Gillings and W. Lawson. (*J. Inst. Fuel*, 1957, **30**, Aug., 446–460).

Gas Converters. W. Holcroft. (*Steel Processing*, 1957, **43**, July, 398–402). Exothermic and endothermic converters for the production of protective atmospheres are surveyed with special reference to control.

Automatic Control of Combustion of Complex Mixtures in Metallurgical Plants. A. Ya. Lerner. (*Stal'*, 1957, (7), 651–655). Circuits have been developed for control of mixtures containing fluxes and oxides.

Explicit Equations for the Calculation, by Successive Approximations, of Equilibrium Gas Compositions at High Temperatures: the Hydrogen + Carbon + Oxygen and the Hydrogen + Carbon + Oxygen + Nitrogen Systems Without Solid Carbon Formation. F. J. Weinberg. (*Proc. Roy. Soc.*, 1957, **241A**, July 23, 132–140).

AIR POLLUTION AND SMOKE

The Rise of a Hot Waste Gas Plume. C. H. Bosanquet. (*J. Inst. Fuel*, 1957, **30**, June, 322–328, Discussion 333–338). From stated principles, an equation is developed for finding the track of hot waste gas rising from a chimney in a wind of any velocity.—D. L. C. P.

Maximum Gas Concentration at Ground Level from Industrial Chimneys. A. C. Best. (*J. Inst. Fuel*, 1957, **30**, June, 329–333, Discussion, 333–338). The maximum ground-level gas-concentration from a chimney depends on the height of rise of the gas plume. Three formulæ determining the latter (Sutton, Bosanquet, Oak Ridge) all lead to similar values of the former. The Oak Ridge formula is simplest and is adequate for this purpose.—D. L. C. P.

TEMPERATURE MEASUREMENT AND CONTROL

A Brief Survey of Pyrometers and Thermometers for Use in the Metallurgical Industry. T. Johánek. (*Hutník*, 1957, **7**, (4), 130–134). [In Czech].—P. F.

Installation for Calibrating Tungsten-Molybdenum Thermocouples. S. H. Danishevskii. (*Zavodskaya Laboratoriya*, 1956, **22**, (10), 1235–1240). [In Russian]. Operating details are given of a previously described installation for the high temperature calibration of W–Mo thermocouples for steel temperature determinations. The method is in successful large scale use.—S. K.

A Method for the Continuous Measurement of Liquid Steel Temperature in the Ladle. R. Katakura, H. Miwa and Y. Wada. (*Sumitomo Metals*, 1957, **9**, Jan., 13–20). [In Japanese]. Liquid steel temperatures have been continuously measured in ladles of various sizes, using an immersion thermocouple sheathed with fused alumina and protected by alumina cement and a steel tube. The temperature difference of steel between the bottom of the ladle and that measured by a rapid immersion pyrometer at other places is ± 20° C. The difference between the temperature in the ladle and that in the trough during casting is only 6° C. The technique is thus suitable for investigating ladle cooling of steel and also for controlling the casting operation.—K. E. J.

New Instrument System Speeds Accurate Checks of Molten Metal Temperatures in Foundry Operations. (*Indust. Heating*, 1957, **24**, July, 1330, 1332, 1334). An immersion thermocouple system operating up to 3200° F is described.

REFRACTORY MATERIALS

A Survey of the Scope for Refractories. D. Dixon. (*Refractories J.*, 1957, **33**, July, 288–292, 298). Primarily a market survey but iron and steel plant refractories are considered with a view to changes in requirements; also ceramics and non-ferrous metal furnaces are reviewed.

Refractories. D. M. Humby. (*Castings*, 1957, **3**, Mar., 22, 23, 25, 27–31, 33). The various types of refractory materials are reviewed. Their properties and uses are briefly discussed with particular reference to foundry applications and to the products of Newbold General Refractories Ltd., Mayfield, N.S.W., Aust.—B. C. W.

Production of Calcined Magnesite. F. W. Menzl and R. E. Sutton. (*Min. Eng.*, 1957, **9**, July, 753–755). The process as carried out at Gabbs, Nevada, is described.

New Basic Refractories. J. Sövegjártó. (*Kohászati Lapok*, 1954, **9**, July, 314–319). The author refers to Hungarian experiments on the production of synthetic magnesite and forsterite as well as of stabilised dolomite. To obtain synthetic magnesite from calcined dolomite three methods were used based on the following processes: (1) Calcined dolomite was treated with sugar solution and magnesium oxide was obtained after precipitation of lime sucrate. This method is not economic. (2) Soluble magnesium hydrocarbonate was produced by treating calcined dolomite with CO_2. (3) Calcined dolomite suspension was treated with $MgCl_2$ and the reaction product was $Mg(OH)_2$. For the stabilizing of dolomite P_2O_5 was used and serpentine with talc was applied to convert CaO to silicate. Synthetic forsterite was made from Hungarian serpentine and talc.—P. K.

Manufacture of Refractory Ware for Use in Metallurgical Laboratories. R. Pointud and J. Roger. (*Rev. Mét.*, 1957, **54**, Apr., 283–287). Techniques used by the authors to manufacture, in the laboratory, crucibles and boats of Al_2O_3, MgO, CaO, ThO_2, UO_2 and CaF_2 are described.

Some Factors Having an Influence on the Fired Dimensions of Clay Ware, with Special Reference to Firebricks. C. Edwards. (*Claycraft*, 1957, **30**, June, 468–472; July, 548–549). Clay composition, grain size, extent of weathering, proportion of grog, added water, length of time in moist conditions, mould size, pressure used, free water during moulding, drying, speed of firing and maximum temp., length of time at peak temperature, type of kiln, kiln atmosphere, load distribution and de-airing process are all considered with a few general observations.

Thermal Length Changes of Some Refractory Castables. S. J. Schneider and L. E. Mong. (*Nat. Bur. Standards, J. Res.*, 1957, **59**, July, 1–8). Changes during heating cycles to 110°, 1050° and 1300°C were measured. The dilatometer, and other apparatus, is described. Silica inversions are shown, the 110° C group show cement reactions, loss of water from hydrates and conversion of amorphous to γ-Al_2O_3.

Influence of the Bulk Density of Chromites on the Bursting Tendency of Chrome-magnesite Bricks. C. Booth and C. Hedley. (*Trans. Brit. Ceram. Soc.*, 1957, **56**, Apr., 185–189). An attempt to correlate the bursting tendency of chrome-magnesite products with variations in the bulk densities of chromites is reported. The evidence suggests that a chromite, the bulk density of which decreases on calcination, may be expected to produce a brick of high iron-oxide-bursting tendency.—D. L. C. P.

The Development of Bond Strength During Firing: A New Approach and its Technological Implications. D. H. Houseman. (*Refract. J.*, 1957, **33**, Apr., 146–153. Discussion 154–158). The principle aim of the work described was to examine the changes that occur during the firing of a wide range of refractory materials, in order to build up a broad picture of bond strength development. The following factors may be important when considering the probable performance of a brick in relation to its bond characteristics:—peak temperature; peak strength; rate of fall of strength with temperature above the peak. In the discussion the value of high temperature firing, and the strength of silica brick were considered.—D. L. C. P.

Petrological Determination of the Suitability of Chromite for Chrome-magnesite Bricks. T. R. Lynam and A. Nicholson. (*Trans. Brit. Ceram. Soc.*, 1957, **56**, Apr., 190–195). An attempt to correlate the growth of chrome-magnesite products with properties which could be readily determined, revealed that a rapid petrological examination of the chromite may be used to estimate the bursting tendency of bricks during kiln firing, and on subsequent exposure to iron oxide. Growth tendency seems to be related to the surface area of the chromite grains in the ore. The presence of free iron oxide is also considered deleterious.—D. L. C. P.

The Action of MnO and MnO-FeO Mixtures on Aluminosilicate Refractories. F. Ball, H. M. Richardson and G. R. Rigby. (*Trans. Brit. Ceram. Soc.*, 1957, **56**, Apr., 200–216). This paper records the results of a cone deformation study of mixtures of MnO, and of MnO and FeO, with each of 8 bricks, ranging in composition from 95% SiO_2 to 73% Al_2O_3, the crystalline phases formed during the reactions being identified from X-ray powder photographs.—D. L. C. P.

A Contribution to the Study of the Drying of Refractory Linings for Rotary Furnaces. (*Fonderie*, 1957, Apr., 181–183). Some experimental results are given to show the changes with time of the temperature and of the water vapour pressure which occur within a furnace lining during drying.—B. C. W.

IRON AND STEEL—GENERAL

Steel: National Plan for Future Supplies. (*Engineering*, 1957, **184**, Aug. 2, 130–133). The developments of Colvilles Ltd. are quoted to supplement the Report of the Iron and Steel Board.

The Future of the Iron and Steel Industry and Industrial Decentralisation. A. Guédras. (*Mét. Constr. Mécan.*, 1957, **89**, Apr., 303–305). The discovery of natural gas in S.W. France and the expansion of the metallurgical industry will possibly lead to the erection of new works either at Bayonne or at Bordeaux.—B. G. B.

Men and Methods in Swedish Steel Making. E. Öhman. (*Anglo-Swedish Review*, 1957, Apr., 155–158). A review, mainly historical.

Survey of Special Metallurgical Problems of the Iron and Steel Industry of Bosnia. K. Kapetanovic. (*Radex-Rundschau*, 1956, (8), Dec., 367–376). The past and present development of iron and steel making in Bosnia is surveyed. Various methods for recovering the Mn of Mn-rich iron ores have been tried; these are described. The Talbot process used on a 180-ton tilting furnace was found to give high production rates and Mn recovery. The production of rimming steel is discussed.

The Indian Union [Steel Industry]. W. Lauersen, M. Biehl, K. H. Frank and D. Anderson. (*Institut für Weltwirtschaft an der Universität Kiel, Stahlwirtschaftliche Länderberichte*, No. 5, 1956, Dec., pp. 185). A general review is given beginning with the 2nd 5-year Plan. Agriculture and power and mineral industries are outlined and then steel output and external trade, sources of iron and Mn ores and fuels and the industry as a whole are considered. Social, political, economic and geographical aspects are outlined and the 6 large works are briefly described with lists of equipment. Many tables and maps make up the volume.

The Use of Concrete in Buildings in the Metallurgical Industry. J. Paul. (*Hutnické Listy*, 1957, **12**, (5), 401–405). [In Czech]. A technical and economic assessment is made of the merits of concrete and steel structures for works in the metallurgical industry. Monolithic concrete structures are considered to be efficient and suitable; the scope of assembled structures is limited.—P. F.

Investigations at the Ural'skogo Institute of Ferrous Metallurgy. N. F. Dubrov. (*Stal'*, 1957, (7), 666–667). Notes are given on the production of spheroidal briquettes of fluxing ores with subsequent roasting; production of fluxing sinter from different types of ore; automatic measurement of the composition of sinter charges; studies of low-shaft furnaces with modified profiles; injection of O.H. melts with use of O_2 at HTM3; production of original data for automatic regulation of the thickness of strip during cold rolling at the 3-stand continuous mill at MMK; heat treatment of moving steel mill rails by induction heating; improving the magnetic properties of hot-rolled transformer steel; low-alloy steel of increased strength for car construction; increasing the durability of annealing boxes and trays for thin sheet treatment; investigation of fluxes for tinning apparatus; rapid electrochemical scouring and etching effects.

Investigations at the Novo-Tagil Metallurgical Works. D. F. Nagovitsyn and D. M. Rabinovich. (*Stal'*, 1957, (7), 668–670). Notes on the working of the blast furnace

with fluxed sinter, the use of a blast enriched with O_2 for melting iron, the melting of ferromanganese with an enriched blast and on the study of reducing processes and gas distribution in the blast furnace shaft are given. **Carbon Linings in the Blast Furnace.** At Novo-Tagil the fire-clay lining lasts 2–2½ years when it fails by reaction with slag, alkali saturation and attack by zinc. In June 1956 the lower part of the stack of No. 3 furnace was relined with C blocks using C paste for joints. Plate coolers were installed and the lining was heated 3 times as fast as usual and thickness was unchanged after 6 months. **Production of Metal for Wheels.** Wheels were rejected for inclusions, gas bubbles and cracks. Deoxidation by Ca-Si instead of Al improved quality. The metal before tapping must be in the range 1610–1620° C, 3·6 t ingots must be poured in 4–6 min and not less than 0·25% Si must be present. **Control of Temperature of Liquid Steel with Immersion Thermocouples.** (669). **Experiments on the Use of Sinter in O.H. Furnaces.** The use of sinter was compared with the use of Magnitogorsk ore. 10–13% more sinter was required, lime consumption was reduced, P removal improved and steel quality was unchanged. **Introduction of Oxygen into O.H. Furnaces.** Since Feb. 1956 O_2 has been blown through seamless tubes into the flame of 370-t furnaces. Stainless steel nozzles are used, water cooled and inclined at 8° to the horizontal 8 in. above the gas port sole. Using ~9100 m³ with 24·5% O_2 the heat was shortened by 14·6%, productivity raised 15·1% and fuel consumption reduced by 15·8%. **Use of Compressed Air on a 140-t O.H. Furnace.** The air is fed through 2–1½ in. tubes in the upper part of the port. Using 1200–1500 m³/h productivity was increased 9·5% with normal ports and 11·5% with arched ports and roof life increased 6%. **A Study of the Efficiency of Lancing Checkers.** The O.H. furnace checkers were lanced every day at Noro-Tagil but the lower parts remained choked with dust. Water sprays at 10 atm were then used twice monthly and the parts below the checkers blown out with steam without shutting down. The top 8–12 courses were bricked with forsterite leaving channels in the 4th or 8th courses for the lancing tubes. The process took 8 h and resistance was lowered by 3 mm water column and temp. reduced 200° C. At the end the temp. is rapidly restored. **Trials with Slip Magnesite Powder.** A powder containing 50% of the 0·1mm fraction was used for fettling the walls and banks. Dust should be low. **Improving the Technology of Rail Production.** The use of O_2 caused increased sensitivity to flaking. When the O_2 was dried and humidity reduced to 0·98 g/m³ flaking was reduced to 0–2% of the heats. Rail pass design for 95 lb and 110 lb/yard rails was studied and it was concluded that haircracks in rails are generally derived from cracks in ingots and much less often by blowholes. Most cracks are in rails from the tops of ingots, and the best way to reduce cracking is by a pass design with maximum reduction in the middle of the foot and by turning the flanges in trapezoidal passes. This new design reduced haircracks from 2·43 to 0·64%. Flaking is eliminated by rolling from cold blooms which have undergone intermediate cooling in stacks in the cogging mill. **Reducing Defects in Large Section Girders. New Methods of Rolling Ingots on the 1150 Mill. Weld Seams of Rolled Girders from the Rail-Structural Works. Increasing the Life of Ingot Moulds.** Cast iron inoculated with Mg produced without raising cupola temp. was not satisfactory and blowing with O_2 in the tapping spout was tried at 4–14 atm raising metal temp. 40–80° C. Size of graphite inclusions was reduced and some Si, Mn and C were oxidized without change in microstructure. Moulds with riveted or cast straps were used to reduce cracking. Mould life was increased 9–15% by cast straps.

Investigations at the Enakievo Works. V. G. Malinovskii and A. S. Babii. (*Stal'*, 1957, (7), 670–671). Notes are given on optimum sintering conditions, on low-alloy Bessemer steel for a.c. armatures and on Bessemer heats produced with a steam–O_2 blast. (Study of 78 heats showed that with 0·6–0·9% Si in an acid-lined converter normal heat balance was unaffected and dust did not exceed 1·5 g/m³ while productivity increased 30–35%. O_2 consumption was ~57·2 kg/t and steam 41·1 kg/t. Refractory life was unchanged and N_2 content was reduced to 1/5 to 1/8 of normal acid steel and much less than in O.H. rimming steel, H_2 and O_2 are unchanged, rolling behaviour is improved and mechanical properties were improved in spite of increased P (up to 0·07%) and somewhat better than O.H. steel). There are also notes on an improvement in the life of Bessemer converter tuyeres, (fireclay-chrome tuyeres with 10–15% chrome ore lasted 3–4 heats longer than ordinary tuyeres, increasing the length from 26 to 30 in prolonged life by 2–3 heats while change of distribution or position had no effect); on work on the O.H. furnace with basic arches and on deoxidation of rimming steel with ferromanganese in the ladle (shortened tap-to-tap time was obtained, melting losses were reduced by 30% and consumption of Fe-Mn by 23·3% to 4·7 kg/t. With combined furnace and ladle deoxidation (50% Fe-Mn in each) consumption is 5·9 kg/t. A specially constructed spout or hopper is necessary in the ladle for the addition); also on rolling mill passes with high-Cr iron; rolling on a 280 mill, an investigation of the rolling of steel girders; rolling cast slabs from a continuous casting machine; rolling sheets from ingots of modified forms, and a study of the properties of converter steel obtained by top blowing; (killed steel was rolled into rails and rimming steel into 60 × 10 mm strips. The top blown ingots were better than ordinary acid Bessemer steel in quality and rolling properties though no marked differences in structure were shown. No flaking occurred in the experimental rail and mechanical properties were up to standard. Tensile strength was somewhat lower and ductility somewhat higher, possibly due to reduced N and P. Cold shortness range was much lower and near that of O.H. steel and ageing properties were also similar to O.H. and superior to acid Bessemer); investigations of laminations in sheets of Bessemer and O.H. rimming steel and the durability of magnesium (treated iron) rolls.

BLAST-FURNACE PRACTICE AND PRODUCTION OF PIG IRON

Historical and Technical Evolution of the Blast Furnace. G. Grenier. (*Echo Mines*, 1957, June, 339–341). A review. (17 references).

On Some Important Questions Relating to Architecture in the Construction of Metallurgical Plant. M. Konêrza. (*Hutnické Listy*, 1957, **12**, (5), 410–414). [In Czech]. The development of architecture in works design is discussed, including the design of parts of plant, e.g. blast furnaces, and of the whole layout.—P. F.

The Standard French Blast Furnace. R. Dardenne. (*Centre Doc. Sidér. Circ. Inform. Tech.*, 1957, (5), 981–997). The possibility of standardizing French blast furnace design is discussed and a number of objections to standardization are answered. A review is then made of American practice and design showing the present state of standardization.—B. G. B.

The Production of Ore Fines Agglomerates and Their Behaviour in the Blast Furnace. L. von Bogdandy and R. Schmolke. (*Stahl u. Eisen*, 1957, **77**, May 30, 685–693). Pelletizing of very fine ore by conventional methods is difficult owing to lack of gas permeability of the pellets. The author describes two new methods: the low-pressure briquetting process and the "hard-foam" process of the Hüttenwerke Oberhausen. The yield obtained in the hard-foam process may be as high as 85% compared with 50–60% by conventional processes. The behaviour of the hard-foam in the blast furnace was studied by radioisotopes and the proportion of radioactivity in the flue dust to that in the pig iron was measured. The mechanical strength of hard-foam is far superior to that of briquettes.—T. G.

Blast-Furnace Smelting of Fluxed Sinter Made from Krivoi-Rog Ores. I. V. Raspopov, Ya. P. Kulikov, Ya. S. Gorbanev and G. D. Muguev. (*Stal'*, 1957, (2), 99–103). [In Russian]. Operating details are given for a 1300 m³ blast furnace when smelting, (1) ordinary sinter and (2) fluxed sinters of basicity 0·85, 0·9, 1·0, 1·2 and 1·2, made from Krivoi-Rog ores. Operation with the highest basicity was found to be both practicable and economically advantageous. The transition from ordinary sinter to a burden with 65% of 1·0 basicity sinter produced an 8·3% increase in productivity and falls of 16 and 10% in coke rate and iron production costs, respectively; the daily rate of coke burning fell by 0·1 tonnes/m³. For effective use of fluxed sinter fines must be removed, raw material quality must be uniform and furnace chilling avoided. Increased FeO-content is not recommended for strengthening fluxed sinter. The reducibility of fluxed sinter in the furnace was higher than that of ordinary sinter.—S. K.

Some Effects of Charging Size on Blast Furnace Operation. T. Kosuge and K. Kodama. (*Tetsu to Hagane*, 1957, **43**, Apr.,

421–431). [In Japanese]. Extensive operating details are given from Higashida No. 6 furnace at Yawata Works, where different burden sizes were investigated and the optimum sizes determined for magnetite and hematite ores in a 40% sinter practice. The importance of relationships between ore size, reducibility and permeability in the furnace is emphasized.—K. E. J.

A Graphical Method for Calculating the Burden of Blast Furnaces. A. Horváth. (*Kohászati Lapok*, 1955, **10**, June, 244–256). On the basis of analytical data the quantity of the slag-forming parts of different ores can be calculated and by the coordinates so obtained the slag-point of every ore can be assigned in the CaO-SiO_2-Al_2O_3 constitution diagram. In the case of mixtures of these ores the ultimate composition of the slag, or for a required slag composition the proportion of the ores and additions can be determined graphically. These data must be corrected by a factor depending on the composition of the coke ash.—P. K.

Injection of Lime Through the Blast Furnace Tuyeres. P. B. Stubbs. (*Blast Furn. Steel Plant*, 1957, **45**, June, 599–600, 613). The results are described of a 2 month blast furnace trial in which powdered lime, sufficient to flux the coke ash was injected into the tuyeres for one month and no lime was injected for the second month. The results obtained do not indicate any advantages from lime injection.

Utilization of Rolling Scale and Top Gas Washing Mud. A. Schedel. (*Kohászati Lapok*, 1956, **11**, March, 97–100). A proposal is made for utilizing various mixtures of rolling scale and top gas washing mud, O.H. furnace slag, flue dust and finally coke powder after briquetting with cement binder. Use in blast furnaces of the briquettes is suggested.

Appraisal of Blast Furnace Operation. L. Visnyovszky. (*Kohászati Lapok*, 1954, **9**, Dec., 531–536). The author describes a method based on the publication of F. Wesmann and K. Wessels (*Archiv Eisenhüttenwesen*, 1949 (7/8), 211–218). For the appraisal of the operation of blast furnaces by drawing up a balance sheet for Fe, C, N and H.—P. K.

Maintenance of Equilibrium in Blast Furnace Operation. C. E. Agnew. (*Steel*, 1957, **141**, July 29, 120, 123, 126, 129, 132, 134; Aug. 5, 96, 99, 100, 102, 104). The balance between furnace capacity and burden preparation is noted, the effect of heating the blast and a comparison of two furnaces is given one on lean ores and the other on rich lake ores and low ash coke, blowing rate being especially considered. The approach to equilibrium is then formulated and the final conditions outlined.

The Control of Blast-Furnace Blast Temperatures. M. Havelka. (*Hutnické Listy*, 1957, **12**, (5), 461–472). [In Czech]. Czechoslovak equipment for the automatic control of blast temperatures is described. Injection of cold air into the hot air arriving from the Cowper stoves may result in inadequate mixing, as the transit time of the air amounts to but a fraction of a second. In the present arrangement this is prevented by mixing the air within the Cowper stove, into which cold air is blown from six vertically displaced nozzles. The desired final temperature can be attained within a few minutes, and is then maintained within $\pm 5°$ of the pre-set nominal value by electric servo mechanisms. The controllers, their mode of operation and installation are described, and details of works tests carried out at the Kladno Steelworks are given.—P. F.

Corrosion Problems in a Blast Furnace Water-Cooling System. H. B. Lloyd. (*Corrosion Techn.*, 1957, **4**, July, 221–224). The author describes the techniques and designs employed by the Workington Iron and Steel Co. to provide a practical solution to the corrosion problems of a blast-furnace water-cooling system based on a soft water supply. External pipework and stove coolers are dealt with in some detail and it is concluded that further experience will enable stove coolers to be left in position for more than one campaign.

Detonation and Shock Wave. M. Hansen. (*Stahl u. Eisen*, 1957, **77**, June 13, 805–813). The author defines the difference between detonation and explosion and shows the destructive power of shock waves. He quotes a number of accidents in which shock waves were responsible for the heavy damage, e.g. explosions in cupolas, gas mains, flue gas systems, etc. He concludes with the precautions to be taken to protect blast furnaces from shock waves.—T. G.

The Design of Blast Furnace Skip Hoists. I. P. Prikhod'ko and B. A. Levshin. (*Stal'*, 1957, (7), 584–586).

Improvements in the Design of Blast Furnace Scale Cars. C. H. L. Schneider. (*Demag News*, 1956, (141), 26–29). Cars for bucket and skip charging systems are shown.

Discussion on the Ougré Low Shaft Furnace. F. Paschal. (*Centre Doc. Sidér. Circ. Inform. Tech.*, 1957, (5), 999–1001). A paper describing the operation of this furnace appeared in *Rev. Univ. Min.*, 1955, **98**, Feb., 45–67 and the present article is a discussion of this paper held in France at a meeting of the French Blast Furnace Commission.—B. G. B.

Some Aspects of Pig Iron Production in Low Shaft Furnaces and of the L.D. Steelmaking Process. R. Forbath. (*Kohászati Lapok*, 1955, **10**, Apr., 152–156). The author reviews comprehensively pig iron production in low shaft furnaces in Cologne and in Calbe (East Germany) and the L.D. steelmaking process in Donawitz and Linz (Austria), in Canada and in the U.S. He stresses the possibility of further improvement by using oxygen in low shaft furnaces and by the utilization of the gases arising from the process.

Aspects of Pig Iron Production in Electric Furnaces. A. G. Gerasimov. (*Stal'*, 1957, (7), 577–579). The high power requirements due to the conductivity of iron ore melts where the amount of reducing agent is low hampers furnace productivity. In the Angara-Yeniseisk region furnaces are being developed for a daily output of 1000–1500 t but so far only 200 t are being obtained.

Development Work in the Field of the Smelting of Ore Fines. H. Schenck and W. Wenzel. (*Forsch. Wirts. Nordrhein–Westfalen*, 1957, No. 407, pp. 71). Experiments on the smelting of iron in dusts and slags in various types of experimental furnaces are reported.

PROPERTIES, TREATMENT AND USE OF SLAGS

Diffusion of Calcium and Silicon in a Lime-Alumina-Silica Slag. H. Towers and J. Chipman. (*J. Met.*, 1957, **9**, June, 769–773). A tracer study is reported at 1430° C. Heats of activation are also given.

Some Problems Relating to the Constitution of Liquid Slags with Special Reference to the Na_2O-MnO-SiO_2 System. R. Hay, P. T. Carter and S. K. Kabi. (*J. Soc. Glass Techn.*, 1956, **40**, Oct., 429–444). Methods of examination are discussed and liquid immiscibility is considered.

Granulation of Manganese Slags for Steelmaking. D. S. Chikashua, A. I. Metreveli and O. I. Voitenko. (*Stal'*, 1957, (7), 611–615). Slags from the non-fluxing process required granulation in a rotating drum. A hydraulic-pneumatic method was used, or alternatively fines from the charge with normal moisture content were added; coke breeze, limestone fines, manganese slimes and low grade ores were used. Fluxed process slags could be granulated by addition of coke breeze in the hydraulic-pneumatic method.

DIRECT PROCESSES

New Process Makes Rolled Steel Directly From Pig Iron. (*Iron Age*, 1957, **179**, June 27, 97–100). The Stora Powder Steel Process and its products are described. The process consists essentially of the following stages:— granulation of molten pig iron; mixing of the granules with high purity iron-ore concentrates; packing mixture in sheet steel box; decarburizing at 1100° C; rolling the package at 1200° C into a sheet of solid steel. The product is comparable in quality with electric furnace steel; it has shown especially good deep drawing properties and welds normally. Preliminary data indicate that it can be produced for $10 to $20 a ton less than steel made by conventional methods. It is envisaged that the process will be adapted to continuous large scale production.—D. L. C. P.

The Kaldo Steel-Making Process in Rotary Furnaces Using Oxygen. B. Kalling and F. Johansson. (*Stal'*, 1957, (7), 598–600).

PRODUCTION OF STEEL

British Steelmaking Today and Tomorrow. D. J. O. Brandt. (*New Sci.*, 1957, **2**, Aug. 8, 14–17). A general review of traditional and more recent continental processes is given.

Some Aspects of Present Day Steel-making Technology. E. Weigl. (*Kohászati Lapok*, 1954, **9**, Aug., 346–348). The author comments on the influence of adequate manganese content, course of refining, desulphurizing and high melting

and teeming temperatures in up-to-date steel making technology on the quality of steel.—P. K.

Progress of Quality Steel Production. E. Szücs. (*Kohászati Lapok*, 1955, **10**, Feb., 77–90). After defining the notion of steel quality the author discusses, mostly based on Soviet experience, the most suitable melting and teeming methods for rimming steel for deep-drawing sheets and of killed steel for boiler plates and seamless tubes, as well as of steel with high impact resistance at −40° C and of high-strength weldable steels. The two latter types and boiler plate steels are treated in Hungary with Al and Ti. The author stresses the importance of low S content and adequate rolling temperature for rimming steels.—P. K.

The Physical Chemistry of Steelmaking. (*Tisco*, 1957, **4**, July). **Physico-Chemical Principles.** T. Banerjee. (101–108). The thermodynamics of free energy change and the activity concept are outlined with a note on kinetics and heats of activation. **Physical Chemistry of Steelmaking Slags.** B. Prakash. (109–117). A review of composition, properties, thermodynamics, kinetics of molten slags, diffusion coefficients and the ionic concept is given. (30 references). **Physical Chemistry of Oxygen Input into the Steel Bath.** V. G. Paranjpe and S. K. Roy. (118–128). Sources of O_2 and their potentials are considered and the principles regulating transfer are discussed. Gaps in knowledge of the subject are indicated. **Reactions of Carbon.** J. S. Vatchagandhy and P. K. Chakravarty. (129–138). The C elimination reaction is outlined and it is shown that two slow steps, diffusion and bubble formation, prevent attainment of equilibrium. The practical implications of the carbon boil are also considered. (21 references). **Reactions of Silicon.** S. Visvanathan. (139–145). Si oxidation and its exothermic effect in the converter and its role in basic processes are outlined. Existing equilibrium data are considered. **Reactions of Phosphorus.** A. B. Chatterjea. (146–153). Distribution between slag and metal are reviewed. As activities in slag are not known an empirical approach is used or the ionic theory can be applied. (28 references). **Reactions of Sulphur.** V. G. Paranjpe. (154–166). A detailed review of desulphurization is given, considering sources, slag–metal reactions, gas–metal and gas–slag reactions. Sulphur cannot easily be removed except in the electric furnace with carbide slag. **Reactions of Manganese.** G. K. Ogale. (167–174). Manganese distribution between slag and metal is calculated and its activity in slag is estimated. **Reactions of Hydrogen and Nitrogen.** U. V. Bhat. (175–181). Absorption and elimination processes are reviewed. **Deoxidation of Liquid Steel.** D. R. Dhanbhoora. (182–189).

Carbon-Oxygen Reactions in Steelmaking. G. Violi. (*Trieste University, Inst. of Applied Chemistry*, No. 1, 1957). [In Italian]. The author establishes the decarburization reaction occurring with high gas formation and stirring of the bath. At the same time the oxidation of impurities and their transfer to the slag are studied as well as the chemical and thermal homogenization of the bath due to stirring which is accompanied by a rise in temperature. The author shows that by means of this decarburizing reaction it is quite possible to control oxygen content within narrow limits. (25 references).—M. D. J. B.

Use of Oxygen in Iron and Steel Production. G. Grenier. (*Echo Mines*, 1957, March, 147–149). A review. (10 references).

Economics of Oxygen Generating Stations for Steel Mill High and Low Purity Oxygen Applications. A. E. Steele and D. E. Cummings. (*Iron Steel Eng.*, 1957, **34**, June, 114–120). The authors describe oxygen generating stations, (i) for high purity O_2 (99·5%) for critical requirements such as machine and hand scarfing, welding and decarburization (ii) for large volumes of high purity O_2 for top blown converters, (iii) for O.H. furnaces and also, (iv) for low purity (95%) O_2 for non-critical requirements which do not require a standby source of O_2 such as for blast enrichment in blast furnace operation.—M. D. J. B.

Survey of Scrap Preparation in Steel Plants. (*Amer. Iron Steel Inst., Contrib. Met. Steel*, 1955, No. 48, pp. 44). This survey contains questionnaire information from 75 melting shops producing O.H. steel in America. It includes details of the types and siting of scrap preparation equipment; the types and specifications of prepared scrap; loading and charging; scrap inspection; the use of incentive systems in scrap preparation; and methods of dealing with coated scrap.—G. F.

Scrap Baling: New Press Cuts Furnace Charging Time. (*Iron Steel*, 1956, **30**, July, 376). The new scrap baling press at Steel Peech & Tozer compresses into bales about 3500 tons per week of iron and steel scrap. Brief details are given of the press and its sequence of operations.—G. F.

Ingot Moulds. (*Bradley's Magazine*, 1957, Summer, 3–4). Properties with continental specifications and causes of failure are briefly considered.

On the Life of Large Ingot Moulds Made of Ductile Cast Iron. Some Considerations on the Comparison Test. T. Kitashima and T. Kono. (*Tetsu to Hagane*, 1957, **43**, April, 437–444). [In Japanese]. Observations were made with two types of mould, the larger having a weight of 5230 kg and wall thickness of 130 mm. Ductile iron moulds, having a higher resistance to crazing and showing less exfoliation. Pearlite and speroidized graphite are decomposed into massive graphite by repeated heating to 700–750° C. Cracks peculiar to ductile-iron moulds must be prevented by improving casting practice or mould design.—K. E. J.

Manufacture of Ingots without Feeder Heads by the Fonderite Process. M. Mahul. (*Centre Doc. Sidér. Circ. Inform. Tech.*, 1957, (5), 1039–1052). Immediately after casting a powdered addition of Fonderite AC is placed on the ingot top. After a predetermined time this powder is stirred and a second powder Fonderite AST is added. After reaction of this second powder some pellets of dry sand are recovered from the top of the ingot. Results obtained at the Firminy O.H. plant in France where nearly 6000 t of ingots have been cast using this process are described.—B. G. B.

Influence of Sampling on the Production of Steel. L. Stehlik. (*Kohászati Lapok*, 1954, **9**, June, 247–252). A description and the advantages of a sampling method applicable to steel with more than 0·3% carbon are given. The molten steel, deoxidized with Al, must be poured in a thin stream on a shovel moved to and fro horizontally. The sample allowed to set in a small plate should be cooled in water, afterwards broken into fine pieces and sifted through a 50 mesh sieve. The sieved material must be delivered to the laboratory for analysis.—P. K.

Special Bar Raises Killed Steel Yield. R. G. Brown. (*Iron Age*, 1957, **180**, July 4, 88–89). The use and advantages of "Ex-Bar" for killing steel are described. "Ex-Bar" is an Al bar of special cross-section and weight which is fixed in the mould prior to pouring. It melts uniformly below the metal surface and disperses evenly. Cleaner steel and increased product yields results, with lower Al consumption.—D. L. C. P.

Effect of Feeder-Head Shape on Ingot Macrostructure. A. K. Petrov and B. P. Okhrimovich. (*Stal'*, 1957, (2), 130–135). [In Russian]. Macrostructure defects in quality-steel ingots bottom poured at the Zlatoustovskii works are analysed and the effect on them of changes in feeder head shape are described. A head with a broader bottom opening and having specially shaped bricks, leaving the inner part of the ingot-mould exposed, produced ingots with much better top macrostructures since the movement of the crust into the head was not impeded: the yield of sound metal for most steels rose by 1–2%, and ingots tended to become self-stripping.—S. K.

On the Continuous Casting of Steel. B. Knapp. (*V.d.I.Z.*, 1957, **99**, May 21, 673–675). A review of progress on the continuous casting of steel from the early impracticable idea of direct casting through rollers to the plant now in use. In Europe slow casting speeds are employed so that good production rates can only be achieved by multi-stand casting. In the U.S.A. casting speeds are higher. The next development is the combination of continuous casting and rolling into a single process.—J. R. P.

Steel Production Without Pipes and Segregations. E. Weigl. (*Kohászati Lapok*, 1954, **9**, May, 207–216). The principles and economy of continuous steel casting combined with rolling are discussed. The author expects an increase in the yield of blooms from 78 to 86%, in that of plates from 62 to 84%, in the yield of sheets from 43 to 75% and finally in miscellaneous steel products from 60 to 80% by using this method.—P. K.

Continuous Steel Casting and Its Combination With Rolling. F. Arkos. (*Kohászati Lapok*, 1955, **10**, Jan., 7–8). Critical review of historical development and present trends as well

as the economics of continuous casting of steel, also combined with rolling.—P. K.

On the V-Segregates of Large Steel Ingots. M. Kawai. (*Tetsu to Hagane*, 1957, **43**, April, 431–437). [In Japanese]. The formation of V-segregations is explained in terms of the sinking of free crystals through the central molten zone to positions determined by the extent of columnar and dendritic crystallization. The inclination of the zones in practice is related to the height/diameter ratio of the ingot and the diameter-ratio of the free-crystal zone. Flaws in the V-segregation zone are related to manufacturing conditions.

Some Practical Examples of the Origin of Metallic Inhomogeneity in Steels. L. Sass. (*Kohászati Lapok*, 1956, **11**, (9), 406–409). The author proves with a few examples that the origin of metallic inhomogeneity in steel can usually be attributed to poor melting practice such as incomplete solution of alloying metal, or negligence in teeming, for example a piece of metal dropped into the ingot mould before casting.

PRODUCTION OF FERRO-ALLOYS

Smelting of Ferroboron with Low Aluminium Content. L. Visnyovszky and B. Körös. (*Kohászati Lapok*, 1955, **10**, June, 121–127). Hungarian experiments on boron-treated malleable irons and especially on chilled cast iron rolls had shown the necessity for producing ferroboron with low-Al content. A comprehensive reference is made to the various methods and results of such ferroboron production chiefly from colemanite ore.—P. K.

Some Practical Experiences in the Production of the Alloy FeNi 50. L. Romaniak. (*Hutník*, 1957, **7**, (4), 122–127). [In Czech]. The production technology of this alloy, used predominantly for sealing into glass, is discussed. Desoxidation, desulphurization, gas-uptake, deep-drawability, thermal expansion etc. are discussed.—P. F.

Production of Ferromanganese in Large Blast Furnaces. A. F. Zakharov, F. A. Khil'kevich, S. V. Bazilevich and B. L. Lazarev. (*Stal'*, 1957, (7), 580–584). An acid slag and a very hot blast are used. Blast enrichment with O_2 does not require increased humidity nor does it require lower blast temperatures to be used. Horizontal charge distribution requires careful control. The possibilities of using a blast at $>1000°$ C are discussed. More stoves with heat-resisting domes would be needed. Slagging is not complicated nor are difficulties met with at the iron notch. The volume of the furnaces is 1100 m³, O_2 enrichment is 24·3% and high top pressure ½ atm.

Oxygen Boosts Ferromanganese Production. (*Steel*, 1957, **140**, June 24, 139–142). The practice of oxygen enrichment of the blast for 2 Fe-Mn furnaces of U.S. Steel Co. is described, 6% O_2 enrichment is obtained using 95% O_2 from a Linde oxygen plant. Production of the 2 furnaces was increased from 650 to 850 t per day and reduction in coke rate was possible.—D. L. C. P.

The First Ferro-Uranium Made in America. C. T. Patterson. (*Metal Progress*, 1957, **71**, June, 85–89). A short account of the production and use of ferro-uranium in America between 1914 and 1925 is presented.—B. G. B.

FOUNDRY PRACTICE

The Castings Industry of the United Kingdom. D. H. Houseman. (*Castings*, 1957, **3**, Mar., 15, 17, 19, 21). The size and scope of the foundry industry in the United Kingdom is outlined and some of the important post-war developments are described. These include changes in melting practice including oxygen lancing, shell moulding, the CO_2 process, and advances in cleaning methods and health precautions.

Progress Made in the Foundry During the Last Six Months of 1956. P. A. Heller. (*Stahl u. Eisen*, 1957, **77**, July 11, 944–947). For the report on the first six months of 1956 see *ibid.*, 1956, **76**, 1758. A review of the literature dealing with structure and properties is in this instalment. (52 ref).—T. G.

The Cost of Production in Relation to Casting Technology. T. Budinszky. *Kohászati Lapok*, 1955, **10**, Feb., 26–32). The effect of up-to-date moulding and casting techniques such as inoculation, green moulding, shell moulding, centrifugal casting, feeding of iron and steel castings at atmospheric and greater than atmospheric pressure etc. are discussed, but it is suggested that caution is necessary in introducing these methods for general application.—P. K.

Diffusion Phenomena in Founding. J. Prohaszka. (*Kohászati Lapok*, 1954, **9**, Ontöde, Aug., 174–180). Reference is made to the atomic mechanism of diffusion in substitutional and interstitial solid solutions. The connexion between diffusion and changes in chemical potential are discussed. Details are given of the malleablising process for pearlitic cast iron in CO-CO_2 mixture and in wet hydrogen.

Compressed Air Economy in the Foundry. I. Gera. (*Kohászati Lapok*, 1955, **10**, June, Ontöde, 134–138). A graphical method is given for calculation of energy standards of compressed air supply to devices in foundries.—P. K.

Calculation of the Area of Moulding Floors. F. Szandtner. (*Kohászati Lapok*, 1954, **9**, Ontöde, June, 140–144; July, 157–165.) A method of calculating the area of moulding floors is given based on the time and space requirements of the various moulding operations.—P. K.

Scandanavian Foundry Review, D. F. J. (*Foundry Trade J.*, 1957, **103**, Aug. 1, 133–137). **Burmeister and Wain.** (137–139).

The Hungarian Foundry Industry in the Past 10 Years. L. Kalman. (*Kohászati Lapok*, 1955, **10**, Apr., Ontöde, 73–79). The author gives a comprehensive review of the development of the Hungarian foundry industry between 1945 and 1955.—P. K.

The Principles of Foundry Maintenance. G. J. Jenkins. (*Brit. Found.*, 1957, **50**, Aug., 429–432). Organization is discussed in a large steelworks.

Fuel Oil for Foundries. T. Marsden. (*Brit. Found.*, 1957, **50**, June, 324–334). A review of oil burning equipment and efficiency of combustion and performance. Empirical formulæ for heat and pressure losses are given with notes on venting, filtration and ring main and tank design. Burners are discussed in detail and graphs of flame efficiency and temperature, the use of preheated air and foundry uses with approximate fuel consumptions are given.

A Talk on the Cupola. F. Velicogna. (*Fonderia Ital.*, 1957, **6**, June, 243–250). [In Italian]. This article gives considerable data on the cupola. A brief historical review is given followed by a description of the principal design features and leading dimensions, its thermal efficiency and mode of operation.—M. D. J. B.

Present Problems of Cupola Practice. M. Király. (*Kohászati Lapok*, 1955, **10**, Jan., Ontöde, 1–7). The conditions for proper cupola practice are suitable construction of the installation and blower, also proper preparation of the mixture and careful charging.—P. K.

Some Aspects of Raw Material and Energy in Cupola Practice. M. Király. (*Kohászati Lapok*, 1954, **9**, July, Ontöde, 145–157). The connection of the following four main factors in cupola practice is discussed in detail: (1) Iron and coke in the mixture, (2) Air quantity and pressure, (3) Weight of mixture and melting time, (4) Height and volume of the shaft.—P. K.

How We Converted to Water-Cooled Cupolas. J. McConville and A. Fischels. (*Mod. Castings*, 1957, **32**, July, 41–44). Conversion to water cooling, the water contact problem, tuyere troubles and redesign with an offset well, I-beam reinforcement, water tank around melting zone and drain water taken from the bottom of the tank are described and later a water-cooled brick shelf and constant water level were introduced. Final tuyere adjustment and reduced lining thickness are described. Melting rate increased, carbon pick-up and silicon loss occurred and better chemical control was obtained.

A Water Cooled Cupola Installation. A. P. Alexander and W. J. C. Ritchie. (*Engineer Foundryman*, 1957, **21**, Apr., 37–39; discussion 39–42). The design, installation and operation of the first water cooled cupola in S. Africa is described.—A. D. H.

The Hot-Blast Cupola as an Economic Unit for Producing Castings to B.S. 1452, Grade 12. J. Henderson. (*Brit. Found.*, 1957, **50**, June, 309–323). A recent 8 t/h plant is described with charging equipment, slag disposal, water-cooling, recuperator system, instrumentation and operation and control. Comparisons with the cold-blast cupola are given.

Hot Blast Package Reduces Melting Costs. (*Canad. Metals*, 1957, **20**, Apr., 46, 48). Adaptation of hot blast to cupolas is reviewed. An oil-fired unit is described and its effect on melting rate quoted.

Desulphurising Experiments with Different Basic Cupola Linings. F. Varga. (*Kohászati Lapok*, 1956, **11**, (8), 169–176; (9), 201–209). A cupola of 300 mm dia. was lined with magnesite, then with stabilized dolomite and later with corundum bricks. The best results from the melting experiments with regard to the refractory consumption were obtained by using a magnesite lining. Based upon these experiments the author determines the changes of the different metalloid contents in the experimental charges, afterwards he describes the role of basic slag and finally explains the physico-chemical reactions particularly in the basic cupola process.—P. K.

The Development of Melting Furnaces for Steel Foundries. V. Zsák. (*Kohászati Lapok*, 1956, **11**, *Ontöde*, March, 61–65). A short review is given of the development of basic and acid lined O.H. and electric steel melting furnaces and acid Bessemer furnaces for steel foundries. The charge for the Bessemer furnace is usually premelted in a cupola.—P. K.

Ultrasonics in the Foundry. J. Jarvis. (*Brit. Found.*, 1957, **50**, Aug., 400–406). Use with high-duty grey iron castings is described. The importance of the non-destructive detection of deep seated flaws is indicated.

Ultra-light Iron Castings for the Motor Industry. T. Wolverson. (*Brit. Found.*, 1957, **50**, Aug., 395–399). Single-cast piston rings and chill-faced tappets casting is described. Microstructure for good wearing quality is discussed and the influence of graphite structure shown.

Experiments on Grey Cast Irons to Improve Their Quality by Means of Double Inoculation. F. Varga and K. Jánossy. (*Kohászati Lapok*, 1956, **11**, May, Ontöde, 112–115). Double inoculation first with a carbide stabilizer in the tap spout and afterwards with a graphitizer in the ladle reduced the scatter in mechanical properties. The carbide stabilizer was ferroboron, containing 7·0% B and 6·8% Al, and low carbon ferrochrome with 73% Cr; the graphitizing innoculant was ferrosilicon containing 75% Si and calcium silicide with 60% Si. These alloys were broken and sieved to 4 mm grain size. The authors suggest the use of this method for casting, especially of low-carbon hypoeutectic grey iron.—P. K.

Employing Nodular Cast Iron for Casting Instead of Malleable Cast Iron. M. Cseh and O. Rácz. (*Kohászati Lapok*, 1956, **11**, May, 97–102). The mechanical properties and chemical composition of malleable cast iron are compared with those of nodular cast iron. The greatest difference was found in the silicon content. Comparison of the mechanical properties of normal cast iron, malleable iron, nodular cast iron and steel brake shoes for railway rolling stock indicates that a higher Si content results in a deterioration in impact resistance but increases the fluidity and castability besides reducing the tendency to pipe formation. High pouring temperature is important, especially for thinner castings.

Conditions for the Introduction of the Production of Nodular Cast Iron. M. Cseh. (*Kohászati Lapok*, 1954, **9**, Ontöde, Nov., 241–251; Dec., 265–270). After briefly reviewing the historical development of the production of nodular cast iron the author discusses in detail the chemical composition e.g. C, Si, Mn, S, Mg, P and other alloying elements, the heat treatment (annealing, hardening, the determination of hardenability), the casting characteristics (castability, shrinkage, moulding technology), wear resistance, impact resistance, fatigue testing, heat resistance, machinability and weldability of nodular cast iron. Finally he refers to the new trends in its production.—P. K.

Stewarts and Lloyds' Tollcross Steel Foundry. A. R. Parkes. (*Foundry Trade J.*, 1957, **102**, June 13, 723–730).

Problem of Casting Shops in the Old Foundries. S. Tochowicz. (*Hutnik*, 1956, **23**, (3), 101–105). [In Polish]. The problem of bottlenecks created by low efficiency in steel ingots casting is discussed. Detailed recommendations of the reconstruction of the casting shops of some old foundries are put forward.

How a Jobbing Foundry Can be Mechanized. (*Foundry*, 1957, **85**, Mar., 98–111). The recently constructed grey iron foundry at General Metals Corp., Oakland, Calif., is illustrated and described in detail. The foundry produces castings in weight from a few ounces to 20 tons, and makes full use of mechanization and automation.—B. C. W.

Steel Foundry Shows Scrap Can Be Reduced. R. H. Herrmann. (*Foundry*, 1957, **85**, Apr., 122–127). A description is given of the facilities and foundry practice at the Swedish Crucible Steel Co., Detroit, where over the past 5 years the production scrap has been less than 1·68% and returns from customers less than 1%.—B. C. W.

Injection Process Permits Use of High-Scrap Cupola Charge. M. Cohen. (*Foundry*, 1957, **85**, Mar., 158, 160, 162). A brief description is given of the use of the graphite—CaC_2 injection process and the general foundry practice employed at the Western Foundry Co., Tyler, Texas.—B. C. W.

Sulphur in Cast Iron. Godot. (*Usine Nouvelle*, 1957, **13**, Mar. 21, 99, 101, 102). Methods of removing S and the development of cast iron resistant to high-S content are described, with mechanical properties of graphitized test-pieces.

The Design Aspect in Repetition Grey Iron Castings. T. Kappelin and G. Fernheden. (*Gjuteriet*, 1957, **47**, Apr., 57–60). [In Swedish]. Fundamental problems in the design of thin-walled castings are discussed by a foundryman and an engineer, with special reference to wall thickness, dimensional tolerances, pattern draught, fillets and openings for core prints, and removal of core.—L. D. H.

Graphite Formation in Cast Iron. R. Thomson. (*J. Metallurgical Club Royal College of Science and Technology*, 1956–57, (9), 38–39). An outline of the process in which carbon diffuses to a nucleating centre such as a sulphide particle is given.

The Use of Alloyed Irons in the Construction of Heat Engines. I. Bartolini. (*Calore*, 1957, **28**, Jan., 27–33). [In Italian]. The author describes the parts in heat engines which can be made of cast iron. The specific characteristics required of the part and the metal are discussed and details are given of the best cast irons to meet these requirements. The effects of alloying elements are reviewed, particularly Cr, Mo, Ni, V and P. Metal specifications for various heat engine parts are given. (12 references).—M. D. J. B.

Nodular Cast Iron. J. G. Pearce. (*Technology*, 1957, **1**, July, 172). A brief review of the material and its properties, in comparison with other cast irons, is given.

Production of Ferritic Spheroidal Cast Iron with High Elongation. J. Piaskowski. (*Przeglad Odlewnictwa*, 1956, **6**, (4), 110–117). [In Polish]. In order to find a type of ferritic cast iron of high elongation several different methods of production were tested. The recommended method is based on introducing Mg rods into the molten metal. The tabulated results show that by this method iron of 10–20% elongation has been obtained.—K. G.

Production of Spheroidal Cast Iron Castings by the Method of Introduction of Magnesium Rods. A. Jankowski. (*Przeglad Odlewnictwa*, 1956, **6**, (5), 131–139). [In Polish]. A detailed description of the method of production of spheroidal iron by introducing Mg rods is given. This method, described first by R. Rodke has been developed mainly by using cast rods of much larger diameter (e.g. 30 mm). It is claimed that 100% spheroidal graphite is obtained by introducing minimum amount of Mg (0·25–0·35%).—K. G.

Liquid Shrinkage. Problems of Compensation in Steel Castings. E. Lofigden. (*Iron Steel*, 1957, **30**, Apr., 147–148; May, 173–178; June, 224–226). Effects of design and insulating and exothermic materials for feeder heads are reviewed. Gating and feeding methods are then considered particularly for the production of hydraulic cylinders and mould assembly and control considerations are carefully described. Pouring of cylinder castings of various designs with riser systems is illustrated.

Steel Castings—Aircraft Opportunity for the Foundry. H. E. Simmons. (*Western Metals*, 1957, **15**, Apr., 55–56). A discussion of pros and cons in question-and-answer form.

Castings in Alloy Steel. (*Usine Nouvelle*, 1957, June, 49, 51, 52; *Aciers Fins Spéc. Franç.*, 1957, Mar., 14–45). Notes on French production of 12/14% Mn steel, constructional alloy steels, stainless steels and heat-resisting steels are given. Normalized, quenched in air or oil, pearlitic, ferritic and austenitic steel casting are all briefly considered and typical products are shown.

Where to Use Heat Resistant, High Alloy Castings. E. A. Schoefer. (*Mat. Methods*, 1957, **45**, June, 122–125). A guide to Fe–Cr–Ni castings is given. Also data sheets (151, 153, 155).

Deoxidizing With Titanium Eliminates Pin Holes. R. H. Ahles. (*Foundry*, 1957, **85**, Mar., 112). The use of Ti as a deoxidant to prevent pinhole porosity in Cr-Mo and Cr–Mo–V steel castings is briefly described. Optimum properties are obtained with 0·008–0·010% S. With current practice residual Ti varies from 0·01–0·03%. With less than 0·015% the steels have an extremely fine grain size and low hardenability but this can be overcome by austenitizing at 2012° F.

Natural and Synthetic Sands. E. Moltoni. (*Foundera Ital.*, 1957, **6**, March, 106–110). [In Italian]. The foundry properties of natural and synthetic sands are reviewed. The advantages of the synthetic sands are claimed to be better permeability, better cohesion when green and when dry, lower water content for equal plasticity, better refractoriness, more consistant characteristics and the possibility of re-use after treatment.—M. D. J. B.

Selected Investigations of the Irregularities Occurring within Sand Test-Specimens. D. C. Williams. (*Foundry Trade J.*, 1957, **102**, June 27, 785–791). A report of a study of the reproducibility of moulded test specimens is given. Mixtures of sand with bentonite and silica flour or cornflour were used and plasticity, flowability, hardness, moisture evaluation, apparent density (related to ramming conditions) and time effects on 1½ × 2 in. and 2 × 2 in. specimens are tabulated and discussed. Density differences within the test pieces as disclosed by sectioning are particularly considered.

Practical pH Control for Moulding Sand. E. C. Zuppann. (*Foundry*, 1957, **85**, Apr., 106–110). The meaning of pH is explained and it is pointed out that as the pH of a moulding sand can change by the decomposition of the materials in the mix, experiments with test mixes of fresh material can be misleading. The symptons that indicate the need for control of sand pH are summarized and a number of actual examples are given to show the results of pH control. Finally some suggestions are given for setting up a pH control programme.

Plastic Speeds Patternmaking. (*Steel*, 1957, **140**, Feb. 11, 108–109). The use of epoxy resins for making or modifying foundry patterns is described. Considerable savings are possible compared with conventional methods.—D. L. C. P.

Mechanical Moulding. G. Somigli. (*Fonderia Ital.*, 1957, **6**, March, 97–105). [In Italian]. The author describes the progress made in the work, operation and management of iron foundries over the last 10 years. Particular reference is made to the various methods of producing moulds by mechanized methods. Foundry mechanization is also discussed in its wider aspects.—M. D. J. B.

The Kestner Foundry Sand Drier. (*Castings*, 1957, **3**, Dec.-Jan., 19, 21). A brief description is given of a plant for drying sand by a current of hot air.—B. C. W.

Cold-setting Cores. H. A. Bruce. (*Foundry Trade J.*, 1957, **102**, June 13, 717–720). Use of a cold-setting binder that simplifies removal for baking (for a reduced time) is described. Green strength is unimportant, no moisture is present and less gas is evolved, but venting is still necessary. The process is illustrated.

Mould Drying Ovens with Gas Re-circulation. G. Farmesi. (*Fonderia Ital.*, 1957, **6**, March, 111–116). [In Italian]. The author describes the advantages of sand drying ovens with recirculation of gases. Various types of ovens are considered as well as the methods of temperature control.—M. D. J. B.

Cleaning Costs Are Affected By What You Do to a Mould. H. Chappie. (*Foundry*, 1957, **85**, Apr., 116–121). The processes carried out on a mould after ramming are discussed with particular reference to the practice used at the National Supply Co., Torrance, Calif. The processes include cope removal, pattern drawing, mould washing, mould drying, core setting, closing and clamping the moulds, and pouring. Details are given of an experiment carried out to determine the time of drying to give the cleanest castings. Results showed that the moulds should be dried within 10 hours.—B. C. W.

Speedier Production of Cylinder Liners. H. W. Haynes. (*Castings*, 1957, **3**, Feb., 23–25, 27). Hand-ramming and machine-ramming methods for the production of moulds for cylinder liners are compared, and it is shown that in this particular case the hand-ramming method, which is described in detail, takes less time, and is more economical.—B. C. W.

Uses of Cast Iron and Other Materials as Denseners in the Production of Machine-Tool Castings. B. Kirby. (*Foundry Trade J.*, 1957, **102**, June 20, 749–754). Experiments on a stepped pattern showed that SiC was superior to cast iron for use as densener for iron castings.

Investment Casting Defects. A. Hegarty. (*Iron Steel*, 1957, **30**, Aug., 411–413, 418). An illustrated review is given of 14 types of faults.

Interpretation and Correction of Certain Foundry Defects. (*Fonderia*, 1957, **6**, May, 209–211). [In Italian]. Foundry work defects are classified and their causes briefly discussed.

Knock-Out Ventilation in the Foundry. W. D. Bamford F. R. Wilson and J. Bright. (*J. Inst. Heating Ventilating Eng.*, 1957, **25**, Aug., 113–125). The design of a side-draught system and the correlation of its requirements with the movement of moulds and castings is described. The importance of hood profile and size of exhaust inlet are indicated and it is shown that control of thermal currents is easiest as near as possible to the top of the mould and that this also keeps dust-bearing air from the breathing zone. The extraction of fine sand grains was so reduced that dust-collecting equipment was unnecessary. An air blowing system was included but was not essential.

Dust Nuisance in the Foundry. G. Dobos. (*Kohászati Lapok*, 1954, **9**, July, 166–167). The cause of silicosis is the continuous inhalation of quartz particles in sizes less than 5μ, especially 0·5–1μ. The author comments on three principles to diminish this menace in the foundry: (1) Prevention of dust formation and (2) prevention of inhalation of flying dust. (3) Reduction of the use of moulding material with free quartz content. Metal smoke in the foundry is a dispersion of rust and metal powder and oil vapour. It is also very harmful and must be removed by means of ventilation or dust extraction.—P. K.

REHEATING FURNACES AND SOAKING PITS

Up-to-date Soaking Pits. L. Marosváry. (*Kohászati Lapok*, 1954, **9**, May, 193–207). The author reviews the construction, practice and economy of various kinds of soaking pits in Hungary and other countries.—P. K.

Reconstruction of a Continuous Furnace for Small Ingots. V. F. Lifanov. (*Stal'*, 1957, (2), 188–189). [In Russian]. Improvements in the construction of a continuous furnace for ingots weighing 200–210 kg are described which secured an increase of productivity from 15 to 26 tonnes per h for an unchanged length and area of the active hearth of 44m².

Gas-Fired Forging Furnaces Aid Reduction of Metal Losses. A. Q. Smith. (*Indust. Heating*, 1957, **24**, July, 1336, 1338, 1340, 1342). Milwaukee Forge practice is described.

Experience Obtained in the Conversion of Boilers and Heating Furnaces to Oil Firing. K. W. Dockhorn. (*Stahl u. Eisen*, 1957, **77**, July 11, 933–939). A combined rolling mill and forging plant situated in South Germany converted its boilers and furnaces to oil firing because the freight for the coal amounted to more than 40% of the coal price; the experience gained in coal-dust firing during the last 20 years was not sufficiently encouraging to use this type of fuel any longer and the German refineries produce so much fuel oil as a by-product that they can offer it advantageously. The oil consumption is about 125 t per week. Details of the conversion are given.—T. G.

Removal of Slag from Soaking Pits in the Liquid State. M. I. Stukalov, N. S. Onishko, and S. D. Gekhtman. (*Stal'*, 1957, (2), 169–173). [In Russian]. It has been found that by adding a small quantity of boiler cinder the fusion point of soaking pit hearth cinder can be lowered sufficiently for it to be removed in the liquid state with hearth temperatures of 1250–1300° C. Considerable advantages have resulted.

HEAT TREATMENT AND HEAT TREATMENT FURNACES

Atmosphere Control. W. L. Besselman. (*Steel*, 1957, **140**, May 20, 138–142; May 27, 96–97). Methods of continuously analysing furnace atmospheres are explained, and the application of these instruments to automatic control of furnaces and generators is described.—D. L. C. P.

The Heat Treatment of Welded Alloy Steels. Institut International de la Soudure, Commission X. (*Soudage Techn. Connexes*, 1956, **10**, Sep.-Oct., 275–277). Twelve types of steel, including 18–8 stainless, are tabulated and compositions and heat treatments are given.

Heat Treatment Diagram for A.I.S.I. 4024. D. J. Blickwede and R. C. Hess. (*Metal Progress*, 1957, **71**, June, 96B).

Heat Treatment Diagram for A.I.S.I. 52100. D. J. Blickwede and R. C. Hess. (*Metal Progress*, 1957, **72**, July, 96–B). A.I.S.I. 52100 has 1·06% C, 0·32% Si, 1·44% Cr, 0·33% Mn, 0·11% Ni and 0·03% Mo, austenitized at 1550° F.

Steam Treat Tools for Longer Shop Life. F. L. Spangler and M. E. Lackey. (*Iron Age*, 1957, **179**, June 27, 106–108). The principle and process of steam-treating cutting tools

(say for ½ h at 1025° F) are described, and examples given of the benefits of such treatment to tool life.—D. L. C. F.

Rate of Diffusion of Boron in Iron-Base Alloys. M. E. Blanter and N. P. Besedin. (*Metallovedenie i Obrabotka Metallov*, 1955, **1**, (6), 3–9). A study of agents for the transfer of boron to steel surfaces is reported. Borax-boron carbide mixtures were used, these were fused and powdered and a standard treatment of 5 h at 1100° C was applied after which the specimens were cooled in air and washed with boiling water. Case depth was measured and was found to increase as the carbide content was raised to 55%. Addition of fluxes reduced m.p. but decreased efficiency. Rates were measured and the effect of alloying elements examined; in general they decrease case depth. A correlation was suggested between bond strength of boride formed and effect of alloying element on the process.

Steam Atmosphere Heat Treating Boosts Plant Operating Efficiency. F. L. Spangler. (*Metal Treating*, 1957, **8**, May-June, 6–8). The basic principles of steam atmosphere heat treating are outlined and a description given of a furnace specifically designed for this method. A summary is given of some typical applications which include powdered iron compacts, high-speed cutting tools, cast iron and laminated silicon steel. It is claimed that the method yields improved properties of the work and reduces or eliminates finishing operations.—A. H. M.

Heat-Treating Facilities Expanded by California-Doran Heat Treating Co. W. G. Thompson. (*Indust. Heating*, 1957, **24**, June, 1264, 1267, 1269, 1271, 1273, 1274, 1276). Controlled-atmosphere furnaces and a bottom quenching furnace are shown, also a radiant tube pit furnace and a gas-fired 3-zone tower furnace for work up to 4 ft dia. and 16 ft long are described with auxiliary equipment.

Grit Blasting: An Aid to Carburizing Quality. A. J. Schwarzkopf. (*Iron Age*, 1957, **179**, Jan. 24, 71–72). The value of grit-blasting in revealing hardened and soft portions of parts after carburizing is explained.—D. L. C. P.

Continuous Carbon-Restoration in an Atmosphere Generated from Town Gas. R. L. Urquhart and J. G. Ritchie. (*J. Australian Inst. Metals*, 1957, **2**, Apr., 1–12). Bolts produced on a cold-heating plant are recarburized in gas from an endothermic generator in a continuous hardening furnace. A nickel catalyst is used. Operation, control, instrumentation and microstructures are described.

Gas Carburizing and Carbonitriding. L. G. W. Palethorpe. (*J. Australian Inst. Metals*, 1957, **2**, Apr., 27–40). A review of furnaces and methods of atmosphere production and the effects on carburizing steels and subsequent heat treatment is given. Carbonitriding is then described with notes on its uses.

Gas Carburizing and Carbonitriding in Charcoal Base Atmospheres. F. P. Heard. (*J. Australian Inst. Metals*, 1957, **2**, Apr., 13–26). The development and operation of continuous furnaces are described and a new design put forward and analysis and intrumentation discussed.

The Influence of White Cast Iron Hardening on Tensile Properties, Hardness and Structure of Pearlitic Malleable Cast Iron. M. Dubowicki, W. Sakwa and S. Pieprznik. (*Przeglad Odlewnictwa*, 1956, **6**, (4), 97–103). [In Polish]. Experimental investigation of the effect of hardening of white cast iron in oil on the tensile strength and hardness of the pearlitic iron obtained by subsequent annealing was carried out. The main conclusions are: (1) hardening reduces the tensile strength but increases the hardness; (2) hardening reduces substantially (2½ times) the time taken in the process of graphitizing.—K. G.

Coefficient of Heat Exchange During Cooling in the Hardening Process. W. Loskiewicz and S. Gorczyca. (*Hutnik*, 1956, **23**, (7–8), 276–282). [In Polish]. Theory and its limitations of the process of cooling are discussed. The results of experiments carried out by the authors indicate that the coefficient of heat exchange depends greatly on the temperature of the surface of the cooled object.—K. G.

Complex Heat Patterns Flame-Harden Part. (*Iron Age*, 1957, **179**, Jan. 17, 83). The method of flame-hardening selected portions of a hyperbolic-shaped hollow roller is described.

Induction Heating of Steel. E. Hörmann. (*Stahl u. Eisen*, 1957, **77**, Apr. 4, 431–433). The author discusses the principles of induction heating and stresses the effect of the frequency used. Induction heating is usually employed where short-time heating of localized areas is required. Short-time heating is often beneficial to the microstructure and, if steel must be heated above its transformation temperature, it does not affect the grain-size.—T. G.

High-frequency Induction Hardening. E. Höhne. (*V.d.I.Z.* 1957, **99**, Apr. 21, 507–510). Following a statement of the thermal and electrical principles involved, induction hardening machines are described and the choice of steels for hardened gears is briefly discussed.—J. G. W.

Researches on Surface Treatment by High-frequency Electromagnet Induction. M. J. Pomey. (*Union Technique de l'Automobile du Motocycle et du Cycle, Reprint*, 1957, Feb., pp. 30). Investigations of the stripping phenomenon are described in detail, with a tentative mathematical theory. Hardening of gear teeth, treatment of cast iron and the structures and effects produced are described at length.

Influence of Cold-working on the Nitriding of Steel. T. Yokoyama and F. Hashimoto. (*Nippon Kinzoku Gakkai-Si*, 1955, **19**, Apr., 259–263). [In Japanese]. The effects of cold-working on nitriding by ammonia are to promote the chemical reaction as the result of strain. With short nitriding times, the work-hardening effect remains, but it disappears if temperatures above 540° C or times above 10 h are used. Cold-working reduces the hardness but increases the depth of the diffused layer. (13 references).—K. K. J.

The Dependence of the Nitrogen Content on the Carbon Content in Carbo-Nitrided Layers. B. Přenosil. (*Hutnické Listy*, 1957, **12**, (3), 222–227). [In Czech]. Case-hardening in ammonia–propane mixtures was studied. The dependence of the C/N ratio on nitriding conditions was investigated, and the results, as well as theoretical aspects are discussed.—P. F.

Contribution to the Study of the Sulfinuz Process. F. Barbas. (*Usine Nouvelle*, 1957, Special No. Spring, 95–97, 99, 101, 103, 104, 105, 107). A review, giving both composition, frictional studies, theories of the process and its effects, change of properties of materials produced and abstracts of the relevant patents, is presented.

Decarburization of Steel Wires. J. Pechanski. (*Hutnik*, 1956, **23**, (9), 330–336). [In Polish]. The topics discussed by the author include: theories of decarburization of carbon steel; the mathematical analysis of decarburization; the methods of determination of the degree of decarburization. The author investigated experimentally the process of decarburization of steel wire containing 0·75% and 0·53% of carbon. The wire was passed through a muffle furnace heated by coke gas composed of 55·4% H_2, 9·0% CO, 21% CH_4, 2·8% CH, 4·8% CO_2, 0·8% O_2, 6·2% N_2. The furnace atmosphere was found to be strongly oxidizing and decarburizing.—K. G.

Effect of Heating and Cooling on the Mechanical Properties of an Alloy Steel. A. S. Kenneford and T. Williams. (*Chartered Mech. Eng.*, 1957, **4**, June, 292–293). Tests on Cr–Mo steel conforming to B.S.S. En 29 at various temperatures during a heating and cooling cycle through the critical range and cooling at two rates are summarized. Specimens were oil-hardened and tempered, heated to 950° and cooled at 5° C/min or quenched and oil-hardened specimens were heated to 950° and quenched without tempering. A Hounsfield tensometer was used with grips modified for use at high temperature and to allow for quenching *in situ*. Chilled N_2 was used for quenching. Charpy tests were also made.

Ductility of Cold-Rolled Transformer Steel. A. G. Petrenko, A. V. Smirnova and L. A. Kurtova. (*Stal'*, 1957, (5), 453–456). Insufficient ductility is often produced by precipitation of carbide around the grain boundaries. Repeated annealing at 750–850° reduces the quantity of carbide and improves ductility.

On Dimensional Changes of Carbon Steel Bars due to Heating and Cooling. I. H. Sekiguchi and M. Inagaki. (*Nippon Kinzoku Gakkai-Si*, 1955, **19**, Apr., 290–293). [In Japanese]. If bars are heated above the A_1 transformation point and cooled, their dimensions at room temperature change; the changes with air cooling and furnace cooling are similar. The carbon content affects the amount and direction of the change. Repetition of heating above the A_1 point and cooling increases the change, while increase of holding time above the A_1 point reduces it.

Dimensional Changes due to Annealing of Plastically Cold-worked Metals. IV. On Effects of Carbon Content of Carbon Steel Bars. H. Sekiguchi and M. Inagaki. (*Nippon Kinzoku Gakkai-Si*, 1955, **19**, Apr., 286–290). [In Japanese]. With low-temperature annealing of cold-worked low-carbon steel bars, dimensional changes are in the same direction as the deformation caused by working before annealing, but with

high-carbon steel bars they are in the opposite direction. With high-temperature annealing of low-carbon steel bar, the length decreases and diameter increases, irrespective of working. The dimensional changes caused by high-temperature annealing of cold-worked high-carbon steel bars are in the same direction as with low-temperature annealing but are of greater magnitude.—K. E. J.

Sub-Zero Treatment of Quenched Steel. I. On the Effect of the Quenching Temperature and Room Temperature Ageing on Sub-zero Treatment of Quenched Steel. Y. Imai and M. Izumiyama. (*Nippon Kinzoku Gakkai-Si*, 1955, **19**, June, 358–361). [In Japanese]. Results are given for steel containing 1·02% C and 1·35% Cr. A higher quenching temperature causes a lower stabilization of retained austenite. The M_f point of retained autenite is not affected by quenching temperature or room-temperature ageing. Increase of quenching temperature increases the hardness produced by sub-zero treatment. The temperature at which the hardness is increased markedly by sub-zero treatment is higher than the M_s' point measured by dilatometric methods.—K. E. J.

Quenching Oils. (*Usine Nouvelle*, 1957, **13**, June 27, 37–38). Cooling curves and martensite transformation curves are considered, and the mechanism of cooling in quenching fluids, particularly oils, is discussed. Properties and operating conditions are outlined with notes on practical effects.

Quenching Oils in Practice. M. S. Johns. (*Machinery Lloyd*, 1957, **29**, June 29, 53–58). [In English, French and German]. Alternative media and heat-transfer phenomena with liquids and quenching curves are discussed. Properties and uses of oils and oil emulsions are given.

Influencing the Recrystallization of Low-carbon Steel by Means of Strain Tempering (KRK Process). V. M. Kyotani. (*Nippon Kinzoku Gakkai-Si*, 1955, **19**, Apr., 255–258). [In Japanese]. Tests on specimens cold-worked by 75% show that the recrystallization temperature is altered by varying the magnitude of the force applied during strain tempering. A considerable amount of recrystallization is achieved by applying the KRK treatment at a temperature above the recrystallization temperature.—K. E. J.

Spectrographic Determination of the Temperability of Steels. A. Camuñas and E. Asensi Alvarez-Arenas. (*Anal. Fis. Quim.*, 1957, **53B**, May, 353–360). Martensite decomposition and case hardening and other carbon diffusion processes have been studied by a special technique. Hardenability curves derived for carbon and alloy steels agree with conventional metallographic and Jominy tests.

Improving the Performance of Automatic Heat-Treatment Mobile Hearth Furnaces. G. A. Khasin and A. D. Shost'. (*Stal'*, 1957, (7), 640–641). An oil-fired furnace with a 11·8 m^3 hearth is described. Automatic temp. and pressure control without modification of the method of heating the metal does not eliminate temp. gradients from top to bottom of the charge. Uniform and rapid heating can only be attained by maintaining a continuous gas current in the furnace with constant burner operations and no cut-off. To prevent overheating from the burner side the loading must be carefully computed. The period for heat treatment has been cut down by 25% and heating quality was improved. The amount of metal sent for repeated treatment was reduced by 40% (300% for ball bearing steels) and decarburization was reduced.

Specifying Manufacturing Temperatures. J. R. Saul. (*Machine Design*, 1956, **28**, Aug. 9, 91–92). Temperature control during manufacturing processes is necessary to maintain a high degree of precision. This article outlines a method of setting up standards for specifying temperatures at which machine parts should be manufactured according to size and material, to obtain required tolerances.—M. A. K.

Some Experiments on Residual Stress Relieving. A. Takaoki. (*Tetsu. to Hagane*, 1957, **43**, Mar., 481–484). [In Japanese]. Stress-relieving on specimens 70 mm in dia. and 210 mm long was studied by the Sachs method. They were quenched in water from just below the Ac point and reheated for various times (1–90 hours) at various temperatures (100–600° C). Stress relief was directly related to heating temperature, and was hardly affected by the time. The variation of hardness at the surface by tempering was a good guide to the degree of stress relief.—K. E. J.

Rotary Hearth Furnaces Geared for Automation in Shell Production Line. A. Q. Smith. (*Indust. Heating*, 1957, **24**, June, 1128–1130, 1132, 1134, 1136, 1138, 1140, 1142). The Rheem Manufacturing Co. line for 155 mm projectiles is described, with list of equipment, including testing equipment, and sequence of operations.

The Finer Points of Good Heat Treatment. E. H. Francis. (*Australasian Eng.*, 1957, **49**, May 7, 77–79). Experiences of the heat-treatment of springs and similar steel parts are described and connected with austenite-martensite transformation phenomena.

The Tempering of Steels containing Chromium and Vanadium. A. K. Seal and R. W. K. Honeycombe. (*J. Iron Steel Inst.*, 1958, **188**, Jan., 9–15). [This issue].

Austempering of Grey Cast Iron. M. Cseh. (*Kohászati Lapok*, 1954, **9**, May, 105–113). The suitability of grey cast iron for hardening and austempering depends on its combined carbon content, which should be more than 0·4%, and on the shape and distribution of graphite flakes as well as on its alloy content. The wear resistance, tensile strength, hardness and toughness increase simultaneously on using austempering. This indicates its applicability to crankshafts, crank axles, hot dies, gears, cylinder liners etc.—P. K.

Martempering of Tool Steels. Ö. Szabó. (*Kohászati Lapok*, 1955, **10**, June, 262–272). The results of Hungarian experiments show that after martempering the toughness of alloyed tool steels is higher and the distortion and cracking are less than after the usual hardening and tempering.—P. K.

FORGING, STAMPING, DRAWING, AND PRESSING

The Forging of Stainless Steels. (*Acciaio Inossid.*, 1957, **24**, Jan.-Feb., 33–36). [In Italian]. Useful practical hints are given on the procedure to be followed when forging stainless steels.—M. D. J. B.

Hot Working of Stainless Steels. (*Acciaio Inossid.*, 1957, **24**, Jan., Feb., 15–32). [In Italian]. This article describes the hot working characteristics of and the techniques to be adopted with stainless steels. Recommended working temperatures and procedures to be followed for martensitic, ferritic and austenitic steels are given. Considerable technical and statistical information is included and a number of useful graphs is reproduced.—M. D. J. B.

The Choice Between Steam and Pneumatic Operated Hammers. A. Leitereg. (*Kohászati Lapok*, 1956, **11**, Feb., 53–54). The loss of energy of a steam hammer is always greater than that of a pneumatic hammer. In spite of this the choice between the two types depends on the cost of energy and on the length of operating time. In the case of lower cost of energy and longer operating time the steam hammer is preferable. The optimum pressure for a steam hammer is 7 at, and for the pneumatic hammer 5·5 at.—P. K.

Evaluation of Tests for Forgeability. A. B. Draper. (*Amer. Soc. Test. Mat. Bulletin*, 1957, July, 62–68). A review of tests previously used is given, and three components in forgeability are defined, flow stress or internal friction, ductility and external frictional resistance. The two major variables are forging temperature and forging speed. The compression test can supply all three components. Other tests are mentioned. (35 references).

Steels for Casting Dies. (*Precision Metal Molding*, 1957, **15**, Aug., 42). Tables of Trade Names, compositions, heat-treatment and properties are given.

Some Metallurgical Aspects of a Gas Turbine Engine. S. Heslop. (*J. B'gam Met. Soc.*, 1957, **37**, June, 497–523). Advantages of the Rover IS/60 unit in comparison with a conventional 60 b.h.p. reciprocating engine are discussed. Description is given of various parts, their function and material. The rotating guide vanes in the compressor unit are made of 12–14% Cr stainless steel, forged by an up-set method, hardened and tempered to 55–65 tons/sq. in. A 2% Ni-Mo alloy steel is used for the compressor shaft; this is forged, carburized and hardened to give 61–64 Rockwell "C" at the surface with core strength of 50 tons/sq. in. The material used for the turbine nozzle is a forged austenitic Ni-Cr-W steel which is metallurgically stable at the operating temperature of 800° C. The high ductility of this steel (47% elongation) is essential in accommodating thermal stresses.—A. H. M.

Shortcut to Long Runs. Heavy Duty Steel Rule Dies. E. K. Scott. (*Iron Age*, 1957, **180**, July 4, 80–81). Fields for the advantageous application of steel rule dies are described. Heavy-duty dies are now used for long production runs as

opposed to early short-run applications. A table gives minimum life of dies used on eight metals at various thicknesses.—D. L. C. P.

Continuous Press Line Marks Big Advance in Forming. W. G. Patton. (*Iron Age*, 1957, **180**, July 18, 111–113). A continuous production line combining press forming and tube making is described. Chief innovation is the "Wean Flying Press," in which mobile tools stamp the moving strip before it moves on to the forming rolls and welder. Advantages of the continuous operation include increased capacity, less floor space, handling and material in process.—D. L. C. P.

The Properties of Steels for Cold Pressing of Bolts. S. Hájek. (*Hutník*, 1957, **7**, (4), 116–122). [In Czech]. A well documented account is given of the effects of shortcomings in the quality of steels, e.g. porosity, slag inclusions, texture, decarburization etc. on their suitability for cold pressing of bolts. The principal causes of rejects arising from inadequacies of the steel are illustrated. It is suggested that fairly detailed standard specifications relating to the composition and heat treatments of steels suitable for cold pressing and cold heading be introduced without delay.—P. F.

Shock Forming With Explosives. G. N. Rardin. (*Metalworking Prod.*, 1957, **101**, Mar. 17, 448–451). High-tensile stainless steels and Ti alloys, which present difficulties in forming by conventional methods, may respond to shock forming with gunpowder and stronger explosives. This article describes some experimental work carried out by Lockheed Aircraft Corp. California.—M. A. K.

Forming with a Bang. (*Steel*, 1957, **140**, June 10, 142–144). Methods and applications of high velocity forming are described. Explosives can be used by; (1) shaped charges or (2) gases from cartridges forcing a piston or punch through the metal. The high velocity impact press uses high-pressure gases to drive opposing rams. These methods can form metals too tough for working by other means, and other special applications are envisaged.—D. L. C. P.

Turk's-Heads Shape Production Parts. (*Steel*, 1957, **140**, June 17, 104–106). Examples of applications of various types of turk's head are described. Even high alloy and tool steel wire and strip can be successfully shaped.—D. L. C. P.

The Fabrication of Bright-Drawn Steel Bars in the U.S.A. O. Andrieu. (*Stahl u. Eisen*, 1957, **77**, June 27, 853–859). A report of a technical mission to the U.S.A. in which the author compares fabrication methods in the two countries.

Temperature Measurement During the Drawing of Steel Wire.—II. W. Lueg and K. H. Treptow. (*Stahl u. Eisen*, 1957, **77**, June 27, 859–867). In continuation of previous work (*ibid.*, 1956, **76**, 1690), the authors studied the effect of lubricants on drawing force and temperature in the drawing die. The influence of drawing speed, v, on the temperature, t, was also investigated. It was found that t and v are related by an equation of the general form $t = f(v\sqrt{})$. U.T.S. of the wire increased with increase in v.—T. G.

Manufacture of Steel Wire for the Needle Industry. B. Hojna. (*Wire Prod.*, 1957, **6**, June/July, 5, 7–9; from *Strojírenství*, 1956, (11), 751–756). An account of Czecho-Slovak practice is given and heat treatments and metallographic structures are described. Compositions, properties and methods of testing are shown. Illustrations are not reproduced.

Stainless Spring Wire. J. F. Trant. (*Wire Wire Products*, 1957, **32**, July, 761–763, 814–815). A review of composition, tempers, drawing conditions and their effects on hardness and tensile properties is given.

Local Martensite Formation in Steel Wire. T. Nishioka. (*Nippon Kinzoku Gakkai-Si*, 1955, **19**, July, 411–414). [In Japanese, with summary in German]. Local martensite formation impairs the mechanical properties of wire; it is often found after the drawing process or during use of the wire. Martensite is found to form locally if a portion of the wire surface is suddenly heated, e.g. by friction or electrically, and the heat is quickly dissipated through the surrounding cold steel. It is not formed by simply heating the wire locally on the outside, e.g. with a flame, if the strong cooling effect is not operative.—K. E. J.

Designing Steel Shapes for Hot Extrusion and Cold Drawing. R. L. Hugo. (*Machine Design*, 1957, **29**, May 16, 127–130). Typical sections are shown and discussed and principles enunciated.

ROLLING-MILL PRACTICE

Contribution to the Study of Rolling Mill Installations. G. Greniér. (*Echo Mines*, 1957, Jan., 26–30; Feb., 83–84, 89–90; Mar., 153–156; Apr. 209–211; May, 275–278, 281; June, 343–344). **Part I. C. Malleability and flow of metal in hot-rolling.** Rolling theory is outlined and mechanism of deformation and profiles are considered at length. Cooling of rolls is then dealt with and the principles of gauging and degrees of reduction. Temperature effects are then outlined.

The Evaluation of the Mean Resistance to Deformation During the Hot Rolling of Steel. A. Geleji. (*Stahl u. Eisen* 1957, **77**, July 11, 931–933). Geleji's formula for the mean resistance to deformation published in 1942 contained a constant C. He has now found that C is in fact not constant but depends on the diameter of the roll and the reduction per pass; he suggests an improved formula.—T. G.

Investigation of the Process of Diagonal Rolling on a Three-Roll Mill. P. K. Teterin, H. A. Danilov and Yu. V. Manegin. (*Stal'*, 1957, (2), 147–151). [In Russian]. Experiments are described in which the nature of metal flow, the twisting of tubes during rolling and the influence of this on tube quality, billet slip in the rolls, power consumption and motor load in a three-roll tube mill were investigated. Part of the work was done during normal operation of the mill, part under special conditions. From the results, normal values of the axial slip coefficient were found to be 0·64–1·18 the tangential slip being < 1. Roll pressure varied from 8·7 to 34·4 tonnes.—S. K.

The Surface Properties of Rolling-Mill Rolls during Rolling. W. Hesse. (*Stahl u. Eisen*, 1957, **77**, May 30, 715–727). The author discusses the various causes of stress in the roll and their metallurgical effect, i.e. surface cracks, complete failure, etc. He compares theoretical predictions with actual failures which were observed in cold and hot rolling. Recommendations are made to the roll maker and user for diminishing or eliminating failures of rolls.—T. G.

Automatic Upper Roll Adjustment in a Reversing-Mill Stand. A. Winkler. (*Hutnické Listy*, 1957, **12**, (4), 332–335). [In Czech]. A servomechanism, fed from the out-of-balance current of a Wheatstone bridge, is utilized to displace the upper roll in the vertical direction. The principle and circuits are described, and a photograph of the control panel is shown.—P. F.

Manufacturing of Steel Mill Rolls from Nodular Cast Iron. B. Körös. (*Kohászati Lapok*, 1956, **11**, *Ontode*, Jan., 1–8; Feb., 34–43). Reference is made to the satisfactory results of Hungarian experiments with chilled and semi-hard rolls from nodular grey iron, made in the cupola and treated with Mg. The danger of fracture has been reduced by improving the wear resistance of the necks and wobblers of chilled rolls and increasing the tensile strength of semi-hard rolls. The author hopes to obtain similar results with hot sheet rolls from nodular cast iron, treated with Mg and B.—P. K.

Study on Charcoal Pig Iron for Chilled Iron Rolls. I. Structural Characteristics and Gas Contents. K. Otani. (*Tetsu to Hagane*, 1957, **43**, Apr., 444–450). [In Japanese]. Investigations were begun into the reasons why charcoal pig iron is more suitable than other types for chilled iron rolls. These are thought to be related to the contents of N_2, O_2 and other impurities. Three laboratories produced consistent gas analyses for charcoal, coke and electric and remelted pig iron. (24 references).—K. E. J.

Production of Rolls with Cast Passes. A. E. Krivosheev and B. B. Ezerskii. (*Stal'*, 1957, (7), 663–665).

Calculation of the Convexity of Rolls. E. Köves. (*Kohászati Lapok*, 1955, **10**, May, 222–226). A method is given for calculating the convexity of hot-metal rolls from their deflection by the roll load and from their thermal expansion, and for calculating the convextiy of cold metal rolls from the roll pressure at the last pass.—P. K.

Electron Microstructure of the Work Roll for Cold Rolling. II. T. Audo, K. Gokan and K. Arase. (*Tetsu to Hagane*, 1957, **43**, Mar., 451–456). [In Japanese]. Tests on a small specimen of roll material, water-quenched after holding for 3 hours at 860°C, showed that completely spheroidized material produced properly distributed carbides in a fine martensite matrix; imperfectly spheroidized material produced coarse martensite and retained austenite. The holding temperature of 860°C was determined as the optimum by independent tests.—K. E. J.

Bearings of Synthetic Materials for Rolling Mills. L. Frank. (*Kohászati Lapok*, 1956, **11**, March, 100–104). The advantages and disadvantages as well as the construction, characteristics and satisfactory use of roll bearings of synthetic materials are reviewed.—P. K.

Stress and Power Indices for Rolling on a Blooming Mill. T. M. Golubev, L. N. Soroko, M. A. Zaĭkov, M. P. Kaftanov, N. A. Chelyshev, G. A. Sakharov and B. P. Zuev. (*Stal'*, 1957, (2), 141–146). [In Russian]. An extensive series of tests on a blooming mill at the Kuznetskiĭ Metallurgical Combine are reported. Determinations were made of reductions, metal pressure on the rolls (with the aid of 1000-ton induction strain gauges automatically recording stresses), metal temperature by optical pyrometers and operating conditions of the mill motor. The results gave the degree of loading of the motor, electricity consumption, and power for each pass and the loading of various parts of the mill. Reserves of productivity were found for the reducing stand. Possible increases in mill productivity are discussed.—S. K.

New Continuous Rolling Mill for Semi-Finished Products. L. Wegmann. (*Demag News*, 1956, (141), 4–12). A fully illustrated account is given of an installation in Dortmund with a capacity of 90,000 t/month with 12 stands and taking 4·5 t ingots, but designed to operate on 7·5 t ingots later.

Investigation of the Operation of a Light Section-Mill Rolling-Rate Regulator. O. G. Muzalevskiĭ and B. B. Lur'e. (*Stal'*, 1957, (2), 135–140). [In Russian]. Descriptions and the results of the operational analysis of rolling-rate regulators on two light section-mills are given. The regulators work on the principle of the stopping for a fixed period of the roller table feeding the first stand if a billet is on the table when the billet it follows has operated a photo-electric cell after the first stand. It is concluded that this system of automation cannot secure a better control of pauses between the billets on the first stand than is possible manually nor the required constancy of pauses between successive billets as they progress along the stands. Suggestions for improvements include a more rhythmic discharge from furnaces, the stopping of billets by the regulator at a fixed point, constancy of billet length and prevention of slip.—S. K.

The Influence of Roll Calibration on the Sharpness of Edges of Angle-Irons. J. Vojkovský. (*Hutník*, 1957, **7**, (4), 114–116). [In Czech]. The effect of various shapes of roll grooves on the sharpness of the edges is discussed. It is shown that by a suitable design of roll profiles it is possible to roll angle-iron with edges sufficiently sharp to be generally acceptable by consumers, so that finishing processes become unnecessary. Inclusion of such angle-irons into standard specifications is suggested.—P. F.

Making Steel Rails for the World. (*Machinery Lloyd*, 1957, **29**, July 27, 53–56). An account of the Workington Iron and Steel Co's Bessemer and rolling plant is given.

Permanent Way Material Production. United Steels' Workington Plant. (*Metallurgia*, 1957, **56**, July, 3–8, 37).

Progress Report of Investigation of Railroad Rails and Joint Bars. R. E. Cramer and R. S. Jensen. (*Illinois Univ. Eng. Exper. Sta. Bull*, 1957, No. 58, June, pp. 37). **Investigation of Failures in Control-Cooled Railroad Rails.** (3–9). **Rolling-Load Tests of Joint Bars.** (10–30). **Shelly Rail Studies.** (31–37).

Flat Rolling. The Effect of Plant Design and Layout on Capital and Operating Costs. W. F. Cartwright and M. F. Dowding. (*J. Iron Steel Inst.*, 1958, **188**, Jan., 23–35). [This issue].

Hot Planetary Mill. H. M. Walter. (*Iron Steel*, 1957, **30**, July, 367). The author discusses the occurrence of "back fins" in hot planetary mill rolling, and describes and illustrates the probable mechanism of their formation.—G. F.

Rolls Forge Precision Parts. (*Steel*, 1957, **141**, July 8, 97–100). Modern roll forming techniques are described. Basically the method uses shaped rolls or rolls in combination with shaped dies, to precision-form hot or cold work. It can produce tapered parts or other shapes and is used for jet engine blades.—D. L. C. P.

The "Minus Ends" in Rolling Round Sections. P. A. Skobolov. (*Stal'*, 1957, (7), 629–630). During the final stages of rolling vibration of the strip fixed at one end detaches the rolled strip from the collars of the roll. Long roller guides and improved rigidity of rolls and bearings remove the defect.

Closed-Circuit T.V. Speeds Production of Alloy Plate at Lukens Steel Company. (*Indust. Heating*, 1957, **24**, May, 960–962). Nine T.V. cameras enable one man to supervise the operation of alloy steel reheating furnaces and another to control shearing and trimming of the alloy plate.—A. D. H.

Steel Plant Automates Packaging. (*Steel*, 1957, **141**, July 8, 112–113). A mechanized line for wrapping and strapping packages of sheet steel is described. Five men deal with 15 units per h.—D. L. C. P.

Weirton Modernises Its Hot Strip Mill. L. A. Fugassi. (*Iron Steel Eng.*, 1957, **34**, June, 75–82). The article describes the new Weirton 66-in. continuous strip mill which replaces the old 48-in. mill. Technical and operational data are given.—M. D. J. B.

Studies on a Four-High Reversing Cold Strip Mill for Tinplate Rolling. I.—Determination of Power and Force Required and of the Power Efficiency of the Motors. K. H. Spiller. (*Stahl u. Eisen*, 1957, **77**, June 27, 867–874). Measurements were carried out during normal production runs using basic Bessemer and O.H. steels and 3, 5 or 7 passes. The results show the input efficiency of the motors, the loads on the Leonard sets, and the rolling force. Recommendations are made for increase in productivity. **II.—Effect of Rolling Force, Rolling Speed, Strip Tension, and Quantity of Lubricants on the Gauge of the Strip.** P. Funke, Jun. (*Stahl u. Eisen*, 1957, **77**, June 27, 874–881). The author measured the effect of rolling force, rolling speed, forward and back tension, and quantity of lubricants on the gauge of basic Bessemer and O.H. steel strip. Recommendations are made on the optimal reductions per pass according to the U.T.S. of the material and on the best mode of operation to achieve a uniform gauge over the whole length of the strip. Strip tension is one of the most important factors.—T. G.

Incremental Control Equations for Tandem Rolling Mills. J. H. Courcoulas and J. M. Ham. (*Trans. Amer. Inst. Elect. Eng.*, 1956, **75**, Part II, 363–374). A numerical example for a 5-stand mill is worked out.

Applying Magnetic Amplifiers. W. F. Eagan. (*Blast Furn. Steel Plant*, 1957, **45**, June, 618–625). A short review of the use of magnetic amplifiers for controlling electric drives in rolling mills is presented.—B. G. B.

New £200,000 Cold Steel Rolling Plant Opened. (*Engineer Foundryman*, 1957, **22**, June, 35–36). An account of the Italian-financed factory at Johannesburg opened in June.

Analysis of Tandem Cold Reduction Mill with Automatic Gauge Control. R. A. Phillips. (*Trans. Amer. Inst. Elect. Eng.*, 1956, **75**, Part II, 355–363).

Production Design Techniques for Cold Roll Forming. R. T. Angel. (*Machine Design*, 1956, **28**, Dec. 13, 106–112). Factors a designer must consider in specifying cold roll forming as a method for production of parts, advantages and limitations of the process, and auxiliary forming and production operations are discussed together with the use of new metals.

Automatic Gauge Control for Cold Reduction Mills. R. A. Phillips and H. S. Maxwell. (*Iron Steel Eng.*, 1957, **34**, June, 149–156). The authors refer to the mathematical literature published on the behaviour of cold reduction mills. This paper translates the mathematics into words which describe the practical behaviour of various types of cold reduction mills and explains how and why automatic gauge control systems differ for various types of mills.—M. D. J. B.

The Application of Magnetic Separators and Cold Rolling Mill Coolant Systems. A. L. Wilson jun. (*Machinery Lloyd*, 1957, **29**, June 29, 43–44). Types of contamination are classified and their removal described.

Perfecting the 140, 250 and 400 mm Tube-Rolling Mills. A. S. Grishkan, M. Ya. Krichevskiĭ, G. K. Seifulin and N. B. Rozenfel'd. (*Stal'*, 1957, (7), 621–627). The new mills are expected to roll tubes with higher precision and thin-wall and large dia. tubes with saving in metal. These possibilities are not yet altogether realized.

New Wheel Rolling Plant at Nizhne-Tagil. S. V. Makaev, G. V. Kotel'nikov, M. I. Staroseletskiĭ and L. A. Narutskaya. (*Stal'*, 1957, (7), 616–621). The dimensions of the ingot moulds have been standardized and wooden patterns have been found unsatisfactory. Gas-fired soaking pits are described for isothermal treatment and tempering. The whole plant is shown in a diagram and equipment and operation described. The steel analysis is given (0·5–0·7% C, 0·6–0·9% Mn, 0·15–0·35 Si, S max. 0·05%, P max. 0·05%;

it is melted in 140-ton basic O.H. furnaces and cast uphill on bogies. The steel is submitted to a pure boil for 1–1½ hr. with a rate of carbon drop not less than 0·2% per hr. and not less than 0·15% per hr. in the last 30 min. Pouring time is 3½–4½ min. Rejects fell to 2·56% in 1956 for inclusions. Tapping temp. was 1595–1615° C. Trials were also conducted on round blooms rolled in a 1150 mm mill from a 360-t O.H. furnace and top poured. The wheels produced were entirely satisfactory. The main factors were the use of a standard bloom, uniform and fixed temp. for final rolling and carefully constructed presses with accurately coaxial dies. Quality of output for the first half of 1957 is shown.

Rolling Mill Motors. (*Engineer*, 1957, **204**, Aug. 9, 202). Illustrations are given of two large d.c. motors one 7000 h.p. running at 50/100 r.p.m. and of peak capacity 21,000 h.p., the other of 8000 h.p. 65/130/160 r.p.m. with emergency peak rating of 24,000 h.p.

Rectifier Power Supply for a Modern Rod Mill. R. A. Buchanan and W. R. Hodgson. (*Trans. Amer. Inst. Elect. Eng.*, 1956, **75**, Part II, 70–74).

Transient Characteristics of D-C Metal-Rolling Motors and Generators. E. P. Smith. (*Trans. Amer. Inst. Elect. Eng.*, 1956, **75**, Part II, 326–331).

Rotary Shears in Light-Section and Rod Mills. H. Terhaag. (*Demag News*, 1956, (141), 13–14).

Electrical Drive of a Steel Works Cold Cut-Up Line. (*Engineer*, 1957, **204**, July 26, 128–129). The Steel Co. of Wales decoiling, flattening and shearing plant for gauges up to ¼-in. is described.

New Cut-Up Line for ¼-in. Strip. (*Sheet Metal Ind.*, 1957, **34**, Aug., 605–608). An account of the Steel Co. of Wales 74-in. installation.

Automatic Sawing and Drilling Plant for Steel Sections. (*Machine Shop Mag.*, 1957, **18**, Aug., 488–492). An account of the Boulton & Paul works, Norwich.

MACHINERY FOR IRON AND STEEL PLANT

In Abstracts for Oct., 1956, p.231. The heading "Machinery for Iron and Steel Plant" should follow the first abstract in the first column.

Hydraulic Equipment in Steelworks. Application and Experience in a Cold-Rolling Mill. F. E. C. Probyn. (*Iron Coal Trades Rev.*, 1957, **175**, Aug. 9, 309–313). Early difficulties at the Ebbw Vale mill are described.

New Trends in Overhead Crane Engineering. O. Wichern. (*Demag News*, 1956, (141), 1–3). Recent designs by DEMAG are illustrated and commented upon.

Method Study Leads to Product Redesign. N. Bashford and D. Meredith. (*Metalworking Prod.*, 1957, **101**, July 19, 1231–1236). Development of a scrap baling press is described.

Electrical Maintenance at Pueblo Plant of The Colorado Fuel and Iron Corp. H. E. Watson. (*Iron Steel Eng.*, 1957, **34**, June, 104–108). Maintenance organization of the electrical department is described. Organizational charts and details of manning, inspection and maintenance procedures are given. Because of its location the works undertakes more maintenance than is customary.—M. D. J. B.

LUBRICATION

High Temperature Steel Mill Greases. J. Simon. (*Iron Steel Eng.*, 1957, **34**, June, 93–100). The author describes the requirements of and test methods applicable to high temperature steel mill greases. Performance requirements are stressed as well as experiences encountered with centralized systems, characteristics of the high temperature greases and the effect of additives.—M. D. J. B.

The Lubricating Properties and Industrial Application of Pure Molybdenum Disulphide. F. Kuhn-Weiss. (*Metalen*, 1957, **12**, Apr. 30, 148–153, May 15, 169–174). [In German]. MoS_2 lubricants are not claimed to be equal to the usual oil and grease lubricating materials but they are certainly useful in cases where high pressures, temperatures and dynamic stresses are involved. The long article gives consideration to the methods of using MoS_2 for the purpose under discussion, its thermal resistance, frictional coefficient, compounding, practical applications etc. with numerous illustrations and graphs in the text.—F. R. H.

WELDING AND FLAME CUTTING

Steel Welding Speedup. (*Canad. Metals*, 1957, **20**, May, 42, 44). The Dual Shield process with a flux-cored electrode and CO_2 shielding is described for welding mild steel.

Observations on Welding As a Factor in Productivity. H. Gerbeaux. (*Soudage Techn. Connexes*, 1956, **10**, Sept.-Oct., 235–272). An extensive illustrated review of industrial uses of welding, mostly of large scale constructions, oil refineries and chemical plant, heat-exchangers, iron and steel plant and furnaces, and electron discharge tubes and transistors, is presented.

An Example of an Early Metal-Arc Weld Repair. (*Brit. Eng. Boiler Elec. Ins. Techn. Rep.*, 1957, **3**, 156–157). A repair in a beam engine pump rod in 1908 is described and illustrated.

Studies of Welding Arcs Using Various Atmospheres and Power Supplies. T. B. Hazlett and G. M. Gordon. (*Welding J.*, 1957, **36**, Aug., 382s–386s). Arc welding tests on freshly machined A.I.S.I. 1020 rolled plate ¾-in. thick with $\frac{1}{16}$-in. mild steel welding wire with 0·15% C and 1% Mn using straight and reverse polarity arcs are described and illustrated. CO_2, He and A atmospheres were used. Mechanisms of metal transfer were studied by cine photography.

CO_2 Shielded-Arc Welding of Steel. P. C. van der Willingen and L. F. Defize. (*Schweissen u Schneiden*, 1957, **9**, Feb., 50–59). Arc characteristics have been investigated and the behaviour of CO_2 is compared with that of rare gases. Simple arc transfer is found to occur with CO_2. It is found that 2–3 vol. % CO referred to the CO_2 used is lost to the surrounding which may constitute a danger. With CO_2 as a shield, hydrogen is eliminated and a low nitrogen content and superior mechanical properties of the weld are obtained. The use of CO_2 is found suitable for automatic welding processes.—U. E.

Automatic Arc Welding Using CO_2 Shield and a Slag Cover. C. de Rop and H. Schmidt-Bach. (*Schweissen u. Schneiden*, 1957, **9**, April, 146–150). The Arcosare welding method is discussed in which CO_2 gas is used as a shield and the electrode contains slag-forming additions. The welding set-up and equipment are illustrated. The AC/DC welding electrode is shown to have a high melting rate and deep penetration, which are suitable for automatic welding. Physical properties and composition of the weld deposit are given.—U. E.

Development and Applications in France of Argon Arc Welding using Consumable Electrodes. L. Dumoulin. (*Soudage Tech. Connexes*, 1956, **10**, March-April, 87–97). The principal advantages of argon arc welding are given as absence of flux, speed of deposition, semi-automatic operation, visibility of arc and high quality of joints. Its application to welding of Al, light alloys, Cu and alloys, stainless and mild steels and to building-up, and the general precautions to be taken are described.

The Scope of Automatic Submerged-Arc Welding. M. Mosný. (*Zváranie*, 1957, **6**, (4), 109–115). [In Slovak]. Vertical welding with one or several electrodes is discussed. A vertical automatic welding machine designed in the Czechoslovak Welding Institute was used in the researches, on which the discussion is based.—P. F.

Argon-Arc Welding of Tubes. J. Novotný. (*Zváranie*, 1957, **6**, (4), 115–119). [In Slovak]. Details are given of the technology of argon-arc welding, with special reference to the welding of pre-heater tubes of austenitic 17/7 MnCr steel for power plant. Results of metallographic and creep tests showed the welds to be satisfactory.—P. F.

New Developments in Welding Ferritic Steels. P. L. J. Leder. (*Iron Coal Trades Rev.*, 1957, **175**, July 26, 201–205). A review of manual, submerged-arc and gas-shielded methods is given. Basic covered and iron powder electrodes, A and CO_2 shielding and externally fluxed electrodes with CO_2 and flux-cored tubular electrodes with CO_2 are referred to. (15 references).

The Electro-Slag Welding Process. I. V. Kudryavtsev and N. M. Savrina. (*Welding J.*, 1957, **36**, Aug., 381s, 392s from *Welding Production*, 1956, Nov.). Tensile and notch-impact tests are tabulated and fatigue results shown.

Welding Composite Steels—Clad Steels. H. Thielsch. (*Machine Design*, 1956, **28**, May 3, 96–100). There are two

kinds of composite steels, clad steels and applied liners, each with specific advantages. This article compares the two briefly and summarizes the welding of clad steels. **Applied Liners.** July 26, 86–91). Applied liners can be used to obtain corrosion resistance inexpensively in large vessels and structures. This article summarizes the methods of welding the liners to backing steels and joining the composite plates.

Development in Weldable High Strength Structural Steels. H. Hauttmann. (*Schweisstechn.*, 1956, **10**, Dec., 149–155). Uses are discussed.

The Metallurgy of the Welding of Certain Austenitic Heat- and Corrosion-resistant Alloys. A. H. Waterfield and R. P. Culbertson. (*Welding Metal Fab.*, 1957, **25**, July, 244–250). Six alloys, one iron-based and two more iron-containing are considered. Their structures are shown and oxidation effects are considered. The methods used for stainless steels apply in general.

Repair and Maintenance of Parts and Components by Welding. H. Neumann. (*Schweissen u. Schneiden*, 1957, **9**, April, 138–146, May, 194–200). The repair of locomotive boilers by welding is described. The applicability of different welding methods is discussed together with the best choice of electrodes. Automatic welding methods for the repair of locomotive parts are considered. The S.I.C.M.A. welding method and built-up welding are briefly discussed.—U. E.

Autogenous Deposit Welding of Ingot Moulds. R. Simko. (*Kohászati Lapok*, 1956, **11**, *Ontode*, Febr., 45–47). The author describes a Hungarian method of repairing ingot moulds by autogenous deposit welding.—P. K.

Welding of Large and Heavy Sections by the Electro-Slag Method. W. Anders. (*Schweissen u. Schneiden*, 1957, **9**, Jan., 12–24). The electro-slag process as developed in Russia is described. The heat developed by the current J × voltage U is used for melting the metal rod. The welding powder is first melted by the arc which is extinguished as soon as there is a sufficient amount of molten powder available. Two water-cooled copper jaws hold the material together. The welding rod is inserted into the slag bath and melted down and produces a joint without a heat affected zone. Welding conditions and compositions of powder and rod are given. The process is applicable to the welding of large and heavy sections.—U. E.

The Classfication of Structural Steels by Their Welding Characteristics. M. W. Bonhomme. (*Rev. Soudure*, 1957, **13**, (2), 112–116). [In French]. A review is given of the main properties of steels which can be used—and welded—for structural purposes. Reference is made to a number of specifications and to the use which can be made of simple mechanical testing methods to determine the weldability of steels.—M. D. J. B.

Influence of Welding on the Properties of Heat Treated Rimming Steel. A. S. Astaf'ev. (*Stal'*, 1957, (2), 158–162). [In Russian]. An investigation is described of the influence of the thermal cycle of the welding process on the mechanical properties of the base metal and welded joint of rimming steel subjected to one of two types of preliminary heat treatments. With optimal welding conditions the low temperature properties of the seam were satisfactory, the favourable effects of heat treatment on the base metal being retained. These favourable effects could be obtained by hardening, notched specimens then showing no brittleness at 60° C; after artificial ageing, brittle fracture occurred at—40°C.—S. K.

Fatigue Testing of Butt Welds. J. H. Lavery, W. A. Mapp and W. S. Coates. (*Australasian Eng.*, 1957, **49**, May 7, 66–68). High-frequency tests on welded specimens of Australian steels are reported with static and hardness tests corresponding. Findings are in a preliminary stage.

The Testing of Brazing and Soldering Materials and Hard-soldered and Brazed Joints. J. Colbus. (*Schweissen u. Schneiden*, 1957, **9**, March, 110–116). The testing of brazed and soldered joints is discussed and compared with tests recommended by the International Institute of Welding. Factors influencing the strength of butt and lap joints are considered.—U. E.

Application of the Hardness Test in Welding Practice. N. Ludwig. (*Schweissen u. Schneiden*, 1957, **9**, March, 98–102). A survey is given of various hardness test methods including the micro-hardness test, and compared with one another. The application of the hardness test to weld seams is discussed.—U. E.

Weldability Tests. P. Bettzieche. (*Schweissen u. Schneiden*, 1957, **9**, March, 91–93). A survey of weldability tests is given. Various test samples are compared.—U. E.

How To Avoid Trouble with Stainless Welds. G. E. Linnert. (*Steel*, 1957, **140**, June 24, 116–118; July 1, 70–72). Cracks and failures in stainless steel welds are caused by notch effects, stress-corrosion, and surface contamination with, for example, C, Zn or S. The cause, detection and avoidance of these troubles is dealt with.—D. L. C. P.

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kinds of composite steels, clad steels and applied liners, each with specific advantages. This article compares the two briefly and summarizes the welding of clad steels. **Applied Liners.** July 26, 86–91). Applied liners can be used to obtain corrosion resistance inexpensively in large vessels and structures. This article summarizes the methods of welding the liners to backing steels and joining the composite plates.

Development in Weldable High Strength Structural Steels. H. Hauttmann. (*Schweisstechn.*, 1956, **10**, Dec., 149–155). Uses are discussed.

The Metallurgy of the Welding of Certain Austenitic Heat- and Corrosion-resistant Alloys. A. H. Waterfield and R. P. Culbertson. (*Welding Metal Fab.*, 1957, **25**, July, 244–250). Six alloys, one iron-based and two more iron-containing are considered. Their structures are shown and oxidation effects are considered. The methods used for stainless steels apply in general.

Repair and Maintenance of Parts and Components by Welding. H. Neumann. (*Schweissen u. Schneiden*, 1957, **9**, April, 138–146, May, 194–200). The repair of locomotive boilers by welding is described. The applicability of different welding methods is discussed together with the best choice of electrodes. Automatic welding methods for the repair of locomotive parts are considered. The S.I.C.M.A. welding method and built-up welding are briefly discussed.—U. E.

Autogenous Deposit Welding of Ingot Moulds. R. Simko. (*Kohászati Lapok*, 1956, **11**, *Ontode*, Febr., 45–47). The author describes a Hungarian method of repairing ingot moulds by autogenous deposit welding.—P. K.

Welding of Large and Heavy Sections by the Electro-Slag Method. W. Anders. (*Schweissen u. Schneiden*, 1957, **9**, Jan., 12–24). The electro-slag process as developed in Russia is described. The heat developed by the current J × voltage U is used for melting the metal rod. The welding powder is first melted by the arc which is extinguished as soon as there is a sufficient amount of molten powder available. Two water-cooled copper jaws hold the material together. The welding rod is inserted into the slag bath and melted down and produces a joint without a heat affected zone. Welding conditions and compositions of powder and rod are given. The process is applicable to the welding of large and heavy sections.—U. E.

The Classification of Structural Steels by Their Welding Characteristics. M. W. Bonhomme. (*Rev. Soudure*, 1957, **13**, (2), 112–116). [In French]. A review is given of the main properties of steels which can be used—and welded—for structural purposes. Reference is made to a number of specifications and to the use which can be made of simple mechanical testing methods to determine the weldability of steels.—M. D. J. B.

Influence of Welding on the Properties of Heat Treated Rimming Steel. A. S. Astaf'ev. (*Stal'*, 1957, (2), 158–162). [In Russian]. An investigation is described of the influence of the thermal cycle of the welding process on the mechanical properties of the base metal and welded joint of rimming steel subjected to one of two types of preliminary heat treatments. With optimal welding conditions the low temperature properties of the seam were satisfactory, the favourable effects of heat treatment on the base metal being retained. These favourable effects could be obtained by hardening, notched specimens then showing no brittleness at 60° C; after artificial ageing, brittle fracture occurred at −40°C.—S. K.

Fatigue Testing of Butt Welds. J. H. Lavery, W. A. Mapp and W. S. Coates. (*Australasian Eng.*, 1957, **49**, May 7, 66–68). High-frequency tests on welded specimens of Australian steels are reported with static and hardness tests corresponding. Findings are in a preliminary stage.

The Testing of Brazing and Soldering Materials and Hard-soldered and Brazed Joints. J. Colbus. (*Schweissen u. Schneiden*, 1957, **9**, March, 110–116). The testing of brazed and soldered joints is discussed and compared with tests recommended by the International Institute of Welding. Factors influencing the strength of butt and lap joints are considered.—U. E.

Application of the Hardness Test in Welding Practice. N. Ludwig. (*Schweissen u. Schneiden*, 1957, **9**, March, 98–102). A survey is given of various hardness test methods including the micro-hardness test, and compared with one another. The application of the hardness test to weld seams is discussed.—U. E.

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Ranks Open New Plating Shop. (*Indust. Finishing*, 1957, **9**, June, 630–633). An illustrated account of a new installation finishing precision equipment, such as cine cameras and projectors, is presented.

Production of Sheet-Metal Components in Relation to Surface Quality and Finishing Processes. D. H. Lloyd. (*Sheet Metal Ind.*, 1957, **34**, Aug., 577–584). Defects in fabrication, finishing, painting and enamelling are discussed.

Application of Ultrasonics in the Electroplating Industry. T. J. Bulat. (*Metal Finishing*, 1957, **55**, Aug., 65–67). Uses for plating bath activation and pre-heating cleaning are outlined.

A Guide to Fastener Finishes. W. R. Yerger. (*Machine Design*, 1956, **28**, Aug. 23, 149–152). Proper selection of fastener finishes for each application may be governed by many factors such as cost, appearance, strength, corrosion resistance and availability. These are discussed and recommendations are made.—M. A. K.

Nickel Electroplates. (*Mat. Methods*, 1957, **46**, July, 137, 139). Data are tabulated of pretreatments, plating baths, thicknesses of deposits and mechanical properties.

Addition Agents in Nickel Plating. R. B. Fischer and C. E. Ring. (*Plating*, 1956, **43**, Nov., 1338–1341). The effect of the addition of 1 : 5-naphthalenedisulphonic acid and saccharin respectively on the properties of nickel electrodeposited from a Watts-type bath was studied by electron microscopical, X-ray diffraction and reflectance tests. Both additions increased specular reflectance and decreased grain size and the diffuse reflectance of deposits 0·001 in. thickness. The optimum concentrations were 0·3–0·5 gm/l. 1 : 5-naphthalenedisulphonic acid or 0·1–0·2 gm/l. saccharin. Deposits of 2×10^{-4} in. in thickness were unaltered by the addition of 1 : 5-naphthalenedisulphonic acid.—A. D. H.

Metallographic Study of Hot Dipped Zinc Coatings. A. T. Baldwin and W. H. McMullen. (*Wire Wire Products*, 1957, **32**, June, 662–663). The compositions of the layers (eta, zeta, delta) and the occurrence of a γ-phase are noted and illustrated and their structures described.

Surface Treatment of Hot-Galvanized Sheet Produced in Liskovec. J. Teindl and A. Hrbek. (*Hutnické Listy*, 1957, **12**, (4), 329–332). [In Czech]. On the basis of their own experience the authors recommend the Protecta-Tin process for the prevention of corrosion of tinplate used in box manufacture.—P. F.

Instrumentation for Galvanizing Control. (*Steel*, 1957, **140**, June 17, 112–116). The method of control of the continuous Sendzimir galvanizing plant at Armco Steel Corp. is described.—D. L. C. F.

Some Observations on Galvanising Embrittlement of Malleable Iron. R. W. Sandelin. (*Amer. Found. Soc. Preprint*, 1957, No. 57–24, pp. 8). Results are presented of an investigation into the effects of silicon and phosphorus, and of heat-treatment on the occurrence of galvanizing embrittlement in malleable iron. The susceptibility to embrittlement was determined by room temperature impact tests on notched bars. Embrittlement was found to be directly related to both the Si and P content, and a graph is given to show the combinations of these elements at which embrittlement may be expected. Embrittlement is prevented by water-quenching from 1200° F before galvanizing, and is reduced by slow cooling after galvanizing. No difference in hardness or microstructure could be detected between unembrittled and embrittled irons.—B. C. W.

Galvanising Embrittlement in Cold-bent Steel Pipes. H. Kimizuka, Y. Shimokawa and M. Nakajima. (*Sumitomo Metals*, 1957, **9**, Jan., 5–12). [In Japanese]. Brittleness in pipes which are hot-dip galvanized after cold bending is liable to be caused by the use of low-carbon rimmed steel, very coarse ferrite grain size, severe cold bending and inadequate pickling. Strain-ageing plays an important part; the brittleness increases on low-temperature heating after bending, even without galvanizing. The best remedy is to anneal after bending.—K. E. J.

Anticorrosive Coatings for Marine Applications. R. E. T. Hanson and W. P. Jenkins. (*Corrosion Prevention and Control*, 1957, **4**, June, 45–46). A general account of ship paints and metal pretreatment is given.

POWDER METALLURGY

Choice, Manufacture and Uses of Sintered Metals. H. Silbereisen. (*Met. Ital.*, 1957, **49**, March, 68–76). [In Italian]. The author gives a comprehensive review of modern sintering techniques and the uses of sintered products. The advantages of sintering are discussed, the fabrication of the powders, methods of compression, the processes of sintering, the working of the parts and the general characteristics and behaviour of the products are discussed in some detail. Information is also given on the fields of application and economics of the process. (19 references).—M. D. J. B.

Possibilities of Utilisation of Metal Powders. M. Hauska. (*Kohászati Lapok*, 1955, **10**, June, 281–287). The author reviews the use of various kinds of metal powders in the chemical, metallurgical and metal industries.—P. K.

Perspectives of Development in Metal Powder Production During the Second Five Year Plan Period in Hungary. M. Hauska. (*Kohászati Lapok*, 1956, **11**, (9), 423–428). The Hungarian metal powder industry involves four categories: (1) Iron and metal powders for mass production of metal ceramic and cemented carbide products. (2) Magnetic iron and metal powders for electronic techniques. (3) Special metal powders for vacuum technique. (4) Light and coloured metal and iron metal alloy powders for other metallurgical and chemical purposes. The author deals only with the fourth group and discusses in detail the present manufacturing problems in Hungary such as: labour protection and production security, maintenance, quality supervision, transport, cost price and the shortage of skilled labour. Afterwards he refers to the use and economics of these metal powders.—P. K.

Strong Ductile Tough Stainless Sinterings. (*Precision Met. Molding*, 1957, **15**, Aug., 43, 69). 18–8 Stainless steel powder compacts are used for refrigerator components.

Sintering Investigations Using Factorial Design Experiments. T. L. Myron, C. J. Davis and R. J. Franklin. (*Indust. Heating*, 1957, **24**, May, 947–948). The optimum operating conditions for a small batch sintering unit were investigated in a statistically designed experiment. The results indicated that, (*a*) the use of a ball mill was preferable to a pug mill for mixing the sinter feed, (*b*) a larger fan was needed and (*c*) stricter control of feed was necessary.—A. D. H.

FERRITES, CERMETS, AND CARBIDES

Synthesis of Some Ferrites. H. Kedesdy and A. Tauber. (*Min. Eng.*, 1957, **9**, July, 784–792). Magnetic data are also given for various Ni, Ni-Zn and Mn ferrites.

Effect of Heat Treatment on the Magnetic Properties of the $FeTiO_3$-Fe_2O_3 Solid Solution Series. Y. Ishikawa and S. Akimoto. (*J. Phys. Soc. Japan*, 1957, **12**, July, 834–835).

Magnetic Properties and Associated Microstructure of Zinc-Bearing Square-Loop Ferrites. G. G. Palmer, R. W. Johnston, and R. E. Schultz. (*J. Amer. Ceram. Soc.*, 1957, **40**, Aug. 1, 256–262).

Influence of Porosity on the g-Factor of Ferrites. J. Snieder. (*Appl. Sci. Res.*, 1957, **6B**, (5), 301–311).

Magnetic Dipole Effects in Ferrites. R. A. Johnson and D. W. Healy jun. (*J. Chem. Phys.*, 1957, **26**, May, 1031–1035).

A Theory of the Uniaxial Anisotropy Induced by Magnetic Annealing in Ferrites. S. Taniguchi. (*Sci. Rep. Tôkoku Univ.*, 1947, **9**, June, 196–214).

Magnetic Annealing Effect in Iron-Nickel Ferrites. Y. Aiyama, H. Sekizawa and S. Iida. (*J. Phys. Soc. Japan*, 1957, **12**, June, 742).

PROPERTIES AND TESTS

Chemical Engineering Practice. Vol. 2. Solid State. H. W. Cremer and T. Davies. 1956. (Academic Press Inc. and Butterworths Scientific Publications). **Fundamental Concepts of Matter in the Solid State.** M. J. P. Musgrave. (1–67). A general account of crystal structure and valency theory on wave mechanical lines, with a section on metal crystals and alloys, and the concepts of ferromagnetism and antiferromagnetism and dislocation theory are given. **Significance of Mechanical Properties and their Measurement.** P. G. Forrest and M. J. P. Musgrave. (68–112). A section on X-ray crystallography is followed by a discussion of strength of materials, stress-strain relationships and tensile testing and a table of mechanical properties of engineering materials. Other tests are then outlined and hardness, brittleness and ductility are discussed. Testing machines and various sorts of mechanical and non-destructive methods are then briefly

reviewed. **Alloy Equilibrium Diagrams.** R. N. Parkins. (113–143). The various types are discussed with a few examples. **The Range of Steels.** J. D. Gilchrist. (144–175). The Fe–C diagram is briefly considered and the range and properties of plain carbon steels reviewed. Low alloy and high alloy steels are then discussed with an outline of heat treatment and transformations. **Fatigue in Metals.** P. G. Forrest. (176–208). An outline of the phenomena, test methods and machines, corrosion fatigue and theories of fatigue processes is presented. **Creep in Metals.** P. G. Forrest. (209–241). Typical curves and methods of representation and extrapolation, testing machines, creep strength data of steels and non-ferrous metals and the effects of metallurgical factors and the stress system are reviewed, with a brief section on theories of creep. **Corrosion of Metals.** F. Wormwell and E. L. Evans. (255–341). Oxidation and surface film growth and diffusion processes and the effect of gases other than oxygen are discussed. Atmospheric corrosion and attack by combustion products, immersed corrosion and electrochemical considerations, corrosion by acids, technical aspects of corrosion in petroleum refining, water supply and underground, stress corrosion and corrosion fatigue and fretting are outlined. Methods of prevention by control of environment, by inhibitors and by protective coatings are surveyed. (291 references). **Porous Powder Metallurgical Products for Filtration and Related Uses.** E. Bishop and G. M. Collins. (464–482). **Powder Metallurgy.** I. Jenkins. (483–532). Preparations of powdered metals and their properties with methods of examination for particle size, packing properties and the like are outlined and compacting and sintering processes are reviewed. Engineering components are then considered, both high-density and porous, from iron and non-ferrous metals and from carbides. (63 references).

A Contribution to the Study of the Mechanical Properties of Unalloyed Flake Graphite Cast Irons. M. Ferry. (*Fonderie*, 1957, May, 209–224). A detailed review of the effects of the matrix, form of the graphite, chemical composition, casting thickness, casting temperature, and inoculation on the density, elastic modulus, hardness and tensile strength of flake graphite cast irons with a ferrite-pearlite matrix. The relationships between the various mechanical properties are also considered.—B. C. W.

Some Aspects in the Production and Measurement of Surface Finish. M. A. Chapple. (*Australasian Eng.*, 1957, **49,** May 7, 57–59, 72). Precision grinding, diamond lapping and the checking of surface finishes are reviewed. Microscopical, stylus and other measuring instruments are briefly considered.

Quality Characteristics of Chemical Equipment and their Control Through Nondestructive Testing. C. J. Veith. (*Non-Destructive Test.*, 1957, **15,** Jan.-Feb., 48–53, 59). Seven quality characteristics of material and equipment in a chemical plant that control their safety and serviceability are discussed. They are: method of manufacture, structural integrity, actual use of the specified materials, leak tightness, dimensional tolerances and dimensional stability, surface cleanliness and surface finish.—A. H. M.

The Use of the Analysis of Variance in the Evaluation of Experiments. M. Knotek and J. Janko. (*Hutnické Listy*, 1957, **12,** (5), 423–429). [In Czech]. The basic principles of the analysis of variance are outlined and illustrated by means of examples taken from actual applications in recent researches on metallurgical problems in Czechoslovakia, e.g. the production technology of transformer sheet and the influence of pouring methods on the silica content of cast-irons.—P. F.

Surface Distributions of Dislocations in Metals, II. C. J. Ball. (*Phil. Mag.*, 1957, 8th Series, **2,** Aug. 977–984). Loci of rotation axes for hexagonal, face-centred and body-centred cubic crystals are discussed.

Impurity–Vacancy Interaction in a Metal. L. C. R. Alfred and N. H. March. (*Phil. Mag.*, 1957, 8th Series, **2,** Aug., 985–997). Mott's model is generalized for impurities in univalent metals. The case of Cu is evaluated.

Characteristics of Metals and Alloys Used in Mechanical Engineering and Foundry Work. P. Corbellini. (*Fonderia*, 1957, **6,** May, 197–199). [In Italian]. A brief account is given of the properties which must be looked for in metals and alloys for use in engineering. The principal properties are low cost and ease of work, weldability, hardness and resistance to impact. A table is given which summarizes the mechanical properties of a wide range of metals.—M. D. J. B.

The Plastic State of Steel. J. Němec. (*Hutnické Listy*, 1957, **12,** (4), 315–324). [In Czech]. The stresses and stress systems in metals, particularly in steel, are discussed on the basis of the physical and mechanical theories of plasticity and strength. The scopes of the various criteria of plasticity and fracture are studied experimentally.—P. F.

The Influence of the Structure of Ordinary Cast Irons on Their Elastic Behaviour. P. Le Rolland and E. Plénard. (*Fonderie*, 1957, Mar., 105–112). Results are given of an investigation into the effects of graphite structure and the nature of the matrix on the elastic modulus of flake graphite irons with a ferrite-pearlite matrix. The influence of the graphite structure was studied by varying independently the amount of graphite and the cooling rate. The results are analysed in terms of the interrelation between elastic modulus, graphite flake size, rate of cooling and amount of graphite. The influence of the matrix was studied by heat-treating specimens from the same cast to give different amounts of ferrite and pearlite. The elastic modulus decreased with increasing graphite flake size, increasing amounts of graphite and slower cooling rates. Changing the ferrite-pearlite distribution had only a small effect on the elastic modulus.

The Influence of Graphite on the Mechanical Properties of Unalloyed Flake Graphite Grey Cast Irons. M. Ferry. (*Fonderie*, 1957, Mar., 113–131). Detailed results are given of an investigation into the effects of graphite size and distribution on the density, elastic modulus, hardness and tensile strength of flake graphite irons with a pearlitic matrix. The density was found to be very closely approximated by the relationship $d = 7{\cdot}80 - 0{\cdot}21$ [C% $-(0{\cdot}85 - \frac{1}{3}$ Si%)]. The elastic modulus depended only on the graphite and varied mainly with the graphite flake size. Tensile strength depended more on the graphite than on the matrix.—B. C. W.

Tensile Properties of Zone Refined Iron in the Temperature Range from 298°–4·2° K. R. L. Smith and J. L. Rutherford. (*J. Met.*, 1957, **9,** July, Section 2, 857–864). The higher the purity the lower are the flow stresses and the better the low-temperature ductility. Yield stresses as low as 3800 psi have been observed at room temperature and elongations of 10% at 4·2° K, most of the ductility arising from twinning. Deformation by twinning at 4·2° is not suppressed by pre-straining at room temperature. Slip traces were observed to begin at the ends of previously formed twin traces. Analyses, curves and micrographs are shown. (36 references).

Observations on the Stress-Strain Behaviour of a Series of Unalloyed High-Duty Pearlitic Irons of the Inoculated Type. H. K. Lloyd and J. V. Harding. (*Brit. Found.*, 1957, **50,** July, 352–358). Sand-cast bars of six high-duty pearlitic irons inoculated in the ladle with CaSi were submitted to tensile testing. Microexaminations and chemical analyses were made and modulus of elasticity at different stresses and permanent set are shown as a function of tensile strength.

For High-Temperature Strength: Stainless or Tool Steel? E. A. Loria. (*Iron Age*, 1957, **179,** June 13, 132–135). The strength properties of various stainless and hot work tool steels are compared with design objectives, determined by the requirements of supersonic missiles. Graphs of tensile strength, yield strength and ductility are given. The hot work steels are generally superior.—D. L. C. F.

The Properties of Some Silicon–Manganese Steels. A. S. Kenneford. (*J. Iron Steel Inst.*, 1958, **188,** Jan., 16–22). [This issue].

The Viscosity of Metal Melts. Tung-ping Yao. (*Forsch. Wirts. Nordrhein-Westfalen*, 1956, No. 336, pp. 53). Theories of structure and viscosity in molten metals are reviewed and measurements by the capillary rotary and vibration viscometers are reported, with descriptions of the apparatus used. The systems studied were non-ferrous.

Studies on the Fluidity of Cast Steel. Z. Takao, I. Araki, M. Arikawa, and T. Shimose. (*Tetsu to Hagane*, 1957, **43,** Mar., 457–465). [In Japanese]. A simple and accurate method has been used for measuring fluidity of electric cast steel. The casting temp. has a clear relationship with fluidity. Over-deoxidation or -oxidation of molten steel leads to poor fluidity, as do SiO_2 and Al_2O inclusions. Fluidity increases as the MnO content increases. (21 references).—K. E. J.

Tests for the Determination of the Wetting Temperature on Steel of Bronze Welding Filler Metals. M. Evrard. (*Soudage Techn. Connexes*, 1956, **10,** July-Aug., 211–214). Tests have

shown that the temperature of wetting during brazing is lower than the m.p. of filler metals. They have also demonstrated certain phenomena resulting from the contact between the filler and base metal, in particular, that which leads to fluxing of the base metal with the filler metal. This merits further study to obtain a better understanding of brazing.

Hydrogen Absorption, Embrittlement and Fracture of Steel. A. E. Schuetz and W. D. Robertson. (*Corrosion*, 1957, **13**, July, 437–458; *NACE Techn. Committee Rep.*, 57–17). A report on a four-year programme on the effects of H_2S, particularly with reference to sour gas condensate wells, is presented. H_2S embrittlement was compared with cathodic charging and fracture under constant deformation was studied. H_2 absorption by Fe-Ni alloys was compared with that from H_2SO_4. The permeation rate of H_2 through austenitic, martensitic and ferritic Fe-Ni alloys was measured, and time dependence of static fracture as a function of stress, structure and H_2 concentration was determined. It was concluded that failure is caused by H_2 absorption and factors are internal and applied stresses. Both martensitic and ferritic structures fail and traces of C, O, and N in 10% Ni steel have no detectable effect. As stress cannot be lowered in service below the endurance limit, H_2 must be eliminated. Dead load tests are necessary in the environment before safe operation conditions can be defined.

Flaking in Steel. F. Feeg. (*Radex-Rundschau*, 1957, Feb., 470–475). The reported tests of various workers shows that the principal cause of flaking in hot worked steel is the pressure set up by H_2 coming out of solid solution. Segregation, stresses set up during cooling and phase changes favour flake formation, but do not of themselves cause flakes though they determine the direction of the flakes in forged material. The measures necessary to minimize flaking depend on promoting a low H_2 content in the steel; this can be reduced in liquid steel by the use of dry materials and, in solid steel, by diffusing H_2 out by heat treatment. Repeatedly passing through the gamma-to-alpha transformation range helps in removing H_2 and is important for large forging ingots. As a safety measure cooling through the temperature range 300° C to 100° C after hot-working should be slow, ~1° C per h for steels highly susceptible to flaking.

Effect of Nitrogen Fixation by Aluminium on the Properties of Structural Steels. H.-J. Wiester, W. Bading, H. Riedel, and W. Scholz. (*Stahl u. Eisen*, 1957, **77**, June 13, 773–784). Finely dispersed aluminium nitride inclusions in structural steels have a beneficial effect on grain-size and mechanical strength. The N_2 level of the molten basic Bessemer steel used varied between 0·22 and 0·30% and Al additions of about 1·5 kg/t was used in a production-scale trial to obtain steels with a yield point of 44–50 kg/mm² and a U.T.S. of 60–67 kg/mm² with excellent elongation at fracture. In the normalized condition, the transition temperature was about −100° C and in the aged stage about −40° C. In the normalized condition the N_2 was almost completely fixed, i.e. these steels should not be liable to marked ageing effects. The steels were readily weldable; low carbon content kept the increase in hardness by heating during welding low. The fine grain-size counteracted the effect of P up to 0·1% in notch sensitivity. The production of the steel is described in detail.—T. G.

B.S.C.R.A.'s New Research Station. (*Metallurgia*, 1957, **56**, July, 29–32, 37).

On the Work of an Operational Research Laboratory. E. Kofman. (*Stal'*, 1957, (2), 187–188). [In Russian]. The work of the operational research laboratory started in 1955 at the "Zaporozhstal'" works is outlined.—S. K.

METALLOGRAPHY

Reflection Microscopy of Ferromagnetic Minerals. A. P. Millman. (*Advan. Phys.*, 1957, **6**, July, 323–326).

Two New Measuring Eyepieces for Area and Volume Measurement under a Microscope. A. Hennig. (*Forsch. Ingenieurwesens*, 1957, **23**, (1/2), 71–73). Two new eyepieces incorporating parallel lines of known length and distance apart or lines marked with points at known intervals are described. These are designed to facilitate the sizing by area or volume of small particles under a microscope.—J. R. P.

Seeing That One Micro-Inch Surface Finish. T. E. W. Preston. (*Metalworking Prod.*, 1957, **101**, July 19, 1237–1241). An account of the surface finish interference microscope and its industrial applications.

Surface Metallurgy Solves Production Problems: How To Select and Prepare a Specimen. A. T. Steer. (*Metalworking Prod.*, 1956, **100**, Aug. 3, 1202–1208). The author describes a technique for isolating causes of failure of parts in storage or service by examining the edge of carefully prepared metallographic specimens.—M. A. K.

Production and Research Problems. A. T. Steer. (*Metalworking Prod.*, 1956, **100**, Aug. 10, 1242–1245). See previous abstract. Ibid. The application of the technique is illustrated by reference to specific examples.—M. A. K.

An X-Ray Monochromator for the Quantitative Determination of Phases. F. Khol. (*Hutnické Listy*, 1957, **12**, (4), 299–302). [In Czech]. A bent-crystal monochromator of recent Czechoslovak design is described, and results of tests carried out with it are given. These relate mainly to the determination of retained austenite, carbides and other phases in the surfaces of case-hardened steels.—P. F.

Preparation of Grey Cast Iron Samples for Microscopical Examination. F. Boda. (*Kohászati Lapok*, 1955, **10**, Ontöde, April, 91–95). For the prevention of breaking out of graphite particles the use of white spirit or methyl alcohol as a lubricant is suggested during grinding on coarse emery paper. Wool or silk are preferable to cloth for polishing grey cast iron. Short polishing using light pressure is proposed. Good results can be obtained by alternate electrolytic and mechanical polishing. Longer contact of graphite with water is harmful.—P. K.

A Single Etching Reagent for the Micrographical Examination of Ferritic Martensitic and Austenitic (as well as of Sigma-Phase Stainless and High Speed Steels. G. Catella and C. Giometto. (*Met. Ital.*, 1957, **49**, March, 200–205). [In Italian]. This paper describes researches carried out to find a single reagent which could be used for the microt structural examination of stainless and high speed steels. The authors claim that the most suitable reagent is a 1–2% solution of picric acid in ethanol, 100 ml + hydrochloric acid-10 ml and glacial acetic acid-3 ml. To illustrate the possibilities of the reagent a series of microphotographs of the above mentioned steels are reproduced.—M. D. J. B.

Micropolishing Iron and Steel. F. Boda and Z. Hegedüs. (*Kohászati Lapok*, 1954, **9**, Aug., 348–352). The authors describe micropolishing methods for iron and steel carried out with an instrument made by M. Truers Chemical Laboratory in Copenhagen. The most efficient electrolytes for iron and steel polishing are as follows: (1) 40 ml $HClO_4$ (S.G. 1·2) + 140 ml ethyl alcohol + 20 ml pure glycerine, (2) 60 ml methyl alcohol + 40 ml diethylene glycol monobutyl ether (Butyl Cellosolve) + 10 ml conc. $HClO_4$. Micropolishing and subsequent etching are applicable to routine determination of grain size of soft steels. Micropolishing without subsequent etching is suitable for determination of carbide precipitation and distribution in tool steels.—P. K.

Influence of the Method of Sampling on the Determination of the Quality of Steel. F. Boda, Z. Hegedüs and E. Bartha. (*Kohászati Lapok*, 1954, **9**, Dec., 536–540). The authors comment on the importance of segregation, especially in the chemical analysis of rimming steels, and refer to the necessity for the metallographic examination of the sample in disputed cases.—P. K.

CORROSION

The Science of Corrosion. J. M. Kape. (*Corrosion Prevention and Control*, 1957, **4**, July, 37–41, 52). A review, generally from an electrochemical standpoint, including a non-technical account of protective oxide formation.

Metallic Corrosion and Conservation. W. H. J. Vernon. (*The Conservation of Natural Resources, Inst. Civil Eng.*, 1957, 105–133). A general review with brief discussion of mechanisms, effects of painting and cathodic protection, economic and statistical estimates and specific fields of corrosion such as underground structures, strips, chemical industry and mining is given.

Metallurgy and Corrosion. M. Roubal. (*Hutnické Listy*, 1957, **12**, (5), 414–417). [In Czech]. Various surface treatments such as chromizing, hot-galvanizing etc. are discussed and their effectiveness and suitability for corrosion protection considered.—P. F.

The Use of Statistics in Corrosion Research. G. M. W. Mann. (*J. Appl. Chem.*, 1957, **7**, July, 419–424). A non-mathematical review.

Graphic Representation of the Theory of Local Cells. V. Cupr. (*Werkstoffe Korrosion*, 1957, **8**, July, 385–389). An

empirical relationship between electrode voltage, total voltage at zero current, and coefficients of resistance of the anodic and cathodic areas is given and methods of using it are shown.

A New Method of Direct Observation of Corrosion and of Electrolytic Processes. E. Fuchs and T. Baumann. (*Kohászati Lapok*, 1956, **11**, March, 107–112). A Reichert microscope is fitted with a simple or a more complicated small cell. In the latter the corrosive liquid can be circulated during examination. A suitable electrode may be mounted into the vessel for electropolishing or electrodeposition. An example is given of the use of this method in a series of photomicrographs, made with a minature camera. The photographs show the various phases of electropolishing and etching of a rough-ground mild steel specimen.—P. K.

The Corrosion of Tinplate by Victoria Plum Syrup. F. W. Salt and J. G. N. Thomas. (*J. Iron Steel Inst.*, 1958, **188**, Jan., 36–45). [This issue].

Theory and Practice in Potential Measurements for Cathodic Protection. P. W. Heselgrave. (*Corrosion Prevention and Control*, 1957, **4**, July, 44–48, 52). A lecture followed by discussion.

Marine Cathodic Protection. A. J. Whitehead. (*Corrosion Prevention and Control*, 1957, **4**, June, 59–60). Corrosion of tanker ballast tanks is considered and cathodic protection leading to calcareous film deposition and its maintenance. The impressed current systems for ore carriers and hull protection systems are also referred to.

Cathodic Protection of an Active Ship Using Zinc Anodes. B. H. Tytell and H. S. Preiser. (*Corrosion*, 1957, **13**, Aug., 515–518). Low-Fe Zn anodes were used and hull potential readings taken weekly for 15 months. Protective potentials of −0·85 −0·9 volt at rest and −0·78 volt while under way were used.

Cathodic Protection of Internals of Ships. L. P. Sudrabin. (*Corrosion*, 1957, **13**, July, 466–472). Internal sea water ballast tanks are discussed and the coordination of cathodic protection and ballast practices. Panel tests are reviewed, and the evaluation of protection to internal bulkhead, skin and structural members by non-destructive means. Mechanism of corrosion and cost of protection are considered.

The Application of Cable in Cathodic Protection. M. A. Riordan and R. G. Fisher. (*Corrosion*, 1957, **13**, Aug., 519–526). Suitable conductors and insulations are discussed and economic factors and power loss considered. Polythene insulation and PVC sheathing were the most suitable combination.

Prevention of Corrosion by Water Treatment. T. B. Fielden. (*Corrosion Techn.*, 1957, **4**, July, 225–229). In this article the author is mainly concerned with corrosion and its prevention in boilers and their accessories. The author first considers briefly the mechanism of corrosion and then shows how this is relevant to boiler corrosion and the use of hydrazine as an oxygen scavenger. Caustic cracking is dealt with and, in relation to this, the limitations and applications of the Berk and Schroeder embrittlement detector are discussed. The author concludes by considering after-boiler corrosion and corrosion in cooling systems. (33 references).—L. E. W.

Role of Corrosion Inhibitors in Water Treatment. E. L. Streatfield. (*Corrosion Techn.*, 1957, **4**, July, 239–244). The author considers generally the chief causes and mechanism of corrosion and the functions of inhibitors. The principles involved in the applications of anodic, cathodic and organic inhibitors are discussed and particular reference is made to sodium benzoate and amines. (12 references).

Cationic Films in Steam Plant—Filming Amines Prevent Condensate Line Corrosion. D. Bass and G. G. Sindery. (*Corrosion Techn.*, 1957, **4**, July, 230–234). The causes of corrosion are very briefly dealt with and the roles played by O_2 and CO_2 and the control of their effects are outlined. Then follows a discussion of the protection afforded by amine films. The compositions of those amines which have been proved are indicated and their preparation and methods of application are described. An example is given of the use of film amines in a large American industrial plant.—L. E. W.

Aluminium Chromizing: Strength Plus Corrosion Resistance. G. R. Fulton and R. C. Reed. (*Iron Age*, 1957, **179**, June 6, 102–104). Tests are reported on the aluminium chromizing of carbon and alloy steels. It was found that the process could give a corrosion and oxidation resistant coating without decarburizing the steel and causing loss of strength.

The Surface Rule of Corrosion and the Effect of Inhibitors in Electrochemical Corrosion. H. E. Hömig. (*Werkstoffe Korrosion*, 1957, **8**, June, 312–324). The rule, advanced in 1924, is reviewed and the conditions under which it is valid are discussed. It is shown to be a special case of the fundamental process. By assuming a simplified mechanism for inhibitors the effects can be derived from the surface rule in fair agreement with experiment.

Corrosion Research Laboratories—12, Ministry of Supply Outdoor Exposure Station, Glascoed, Wales—Testing Paints by Outdoor Exposure. C. R. Edwards and E. Jenkins. (*Corrosion Techn.*, 1957, **4**, June, 192–194; July, 245–250). The reasons for the location of the site at Glascoed are given and the site layout, staff organization and equipment are briefly described. The methods adopted for the assessment of panels are then discussed in some detail. A number of photographs of panels is included to illustrate the standards of assessment in terms of loss of gloss, colour change, failure by checking and cracking, chalking, flaking, blistering, rusting, dirt collection, water spotting and erosion.—L. E. W.

Evaluation of Rust-Prevention Oils. H. Roden. (*Amer. Soc. Test. Mat. Bulletin.*, 1957, July, 55–61). A controlled moisture condensation apparatus for testing is described and evaluated and many test results are given.

Protective Plastic Tapes for Anticorrosion Service. W. Kirsch and L. Remy. (*Corrosion et Anticorrosion*, 1957, **5**, Mar., 82–88). Tapes of cellulose, glass fibres and synthetics and their uses are described.

ANALYSIS

Modern Trends in Metallurgical Analysis. W. T. Elwell. (*Iron Steel*, 1957, **30**, July, 347–353). The author discusses recent trends and advances in the science of analytical chemistry. The subjects considered include emission and mass spectrography, X-ray fluorescence, atomic absorption spectra, spectrophotometry, and radioactivation methods of analysis.—G. F.

Sampling Plans in ASTM Specifications. G. H. Harnden, O. P. Beckwith, S. Collier, H. F. Dodge, L. E. Simon and P. J. Smith. (*Amer. Soc. Test. Mat., Bulletin*, 1957, July, 47–51). A review of specifications giving sampling methods with a discussion of whether they should be included.

Some Recent Advances in the Analysis of Cast Iron and Foundry Materials. W. E. Clarke. (*Metallurgia*, 1957, **56**, July, 47–52). Sampling, radio-frequency heating for combustion determinations of C and S, methods for Mg and trace elements (Sb, Pb, Bi), and Al in iron and slags are reviewed (19 references).

Sampling for the Determination of the Hydrogen Content of Liquid Steel and Iron. E. Piper and H. Hagedorn. (*Mét. Constr. Mécan.*, 1957, **89**, April, 329–333). A description is given of the method of detecting hydrogen and ascertaining the quantity present. A comparison is made of three methods of sampling.—B. G. B.

Analysis of Ferro-Alloys. Determination of the Principal Element. (*Fonderie*, 1957, April, 183–186). The sampling of ferro-alloys is discussed and methods suitable for use in a foundry are then given for determining Si in ferro-silicon and Cr in ferro-chrome.—B. C. W.

Colorimetric Estimation of Manganese. W. V. Single. (*Nature*, 1957, **180**, Aug. 3, 250–251). Determination with Tetrabase is discussed. Interference in ion-exchange treated solutions is reported.

Determination of Manganese and Aluminium in Iron-Vanadium Alloy. J. Plank. (*Kohászati Lapok*, 1956, **11**, (9), 428–429). An analytical method using "cupferron" is described.—P. K.

The Absorptiometric Determination of Vanadium in Steel. P. H. Scholes. (*Analyst*, 1957, **82**, July, 525–528). 3 : 3′-Dimethylnaphthidine and tungstophosphoric acid are developed as reagents.

Investigation on Cast Iron Having Refined Graphite Produced by Melting Cast Iron Covered with Slag Containing TiO_2. VI. Determination of Metallic Titanium and Non-Metallic Titanium Compounds Contained in S-H Cast Iron. H. Sawamura and M. Tsuda. (*Tetsu to Hagane*, 1957, **43**, Mar., 471–480). [In Japanese]. The method is based on the assumption that Ti exists in solid solution in iron and as TiC, TiN, TiO, Ti_2O_3, TiO_2 and TiS as stoicheiometric compounds. It is confirmed that about 80% of the Ti in grey cast iron exists as TiC. (31 references).—K. E. J.

Galvanic Oxygen Recorder. P. Hersch. (*Instrument Practice*, 1957, **11**, Aug., 817–823; Sept., 937–941). A device in which O_2 is recorded continuously using a galvanic O_2-depolarized element is described.

Polarographic Oxygen Determination. K. Linhart and J. Žagmen. (*Chemia Analityczna*, 1957, **2**, (2), 183–186). The reaction with chromous ion is used and is applicable in presence of acid gases.

Polarographic Determination of Carbon Monoxide. K. Linhart. (*Chemia Analityczna*, 1957, **2**, (2), 187–192). The I_2O_5 reaction is used and the I_2 formed is oxidized to iodate and determined polarographically. 110° C is the optimum temperature and H_2 interferes.

A Volumetric Determination of Traces of Zinc in Nickel Plating Solutions. T. A. Downey. (*Plating*, 1956, **43**, Nov., 1335–1337). A relatively simple extraction volumetric method using EDTA is described and shown to be reliable in commercial plating baths.—A. D. H.

New Method Speeds Analysis for Salt in Pickling Bath. (*Iron Age*, 1957, **179**, June 6, 105). A rapid method for determining sodium chloride in sulphuric acid pickling baths is described. The salt is added to baths in certain cases to inhibit attack on the steel. The method involves adding to the solution:— silver nitrate, nitric acid, nitrobenzene and ferric ammonium sulphate and titrating with ammonium thiocyanate solution.—D. L. C. F.

New Method for Rapid Analysis of Silicates, Minerals, Ores, Slags, Refractories, etc. J. Sajo. (*Kohászati Lapok*, 1954, **9**, Aug., 353–358). The substance of the method is the treatment of the sample after wetting with KOH in a silver crucible. During this treatment oxidation with Na_2O_2 or, for material with high iron oxide content, reduction with hydrogen or carbon are applied.—P. K.

Rapid Analysis of Limestone and Dolomite. J. Farkas. (*Kohászati Lapok*, 1956, **11**, Jan., 11–13). The author describes a complexometric method for determination of LaO and MgO and a photometric method for estimation Fe_2O_3 in limestone and dolomite.—P. K.

Practical Routine of the Simultaneous Spectrographic Determination of Si, Mn, Cu and Cr in Pig Iron. Y. Niimi and T. Kitahara. (*Sumitomo Metals*, 1957, **9**, Jan., 31–42). [In Japanese]. The procedure investigated was a condensed spark method using a Shimadzu medium quartz spectrometer. Optimum conditions of electrode, shape, excitation, photography, selection of line pairs, etc. were determined. Reproducibility was good, the average deviations ranging from 2·85% for Mn to 5·72% for Cu, and the accuracy was as good as in chemical analysis. A low coefficient of variation was found between daily chemical and spectrographic analyses. 40 min only is needed for analysis.—K. E. J.

Iron-60. J.-C. Roy and T. P. Kohman. (*Canad. J. Phys.*, 1957, **35**, May, 649–655). Artificial preparation of ^{60}Fe and its properties are reported.

The Application of Radio-active Isotopes in the Steel Industry. H. Krainer and E. Krainer. (*Schweiz. Arch. Wiss. Techn.*, 1956, **22**, Dec., 402–413). A number of applications of radioactive isotopes are described. ^{32}P can be used to indicate phosphatic segregations in steel and to show the alterations brought about by forging and heat treatment. The determination of iron mobility of iron in liquid silica slag can be made. Radioactive iron can be used to measure diffusion in 18/8 steel. ^{32}P can be employed for rapid determination of P content. The use of radioactive isotopes to measure tool wear and in conjunction with gamma rays for non-destructive tests are also described.—J. R. P.

INDUSTRIAL USES AND APPLICATIONS

Tool and Die Steels. G. A. Roberts. (*Metal Progress*, 1957, **71**, June, 106–108). A short review is presented of the application of steels, normally used for tool and die purposes, to aircraft construction.—B. G. B.

Future Engineering Development of the Gas-cooled Nuclear Reactor. J. M. Kay. (*J. Iron Steel Inst.*, 1958, **188**, Jan., 3–8). [This issue.]

Spring Alloys. M. G. Fangemann. (*Machine Design*, 1956, **28**, May 31, 121–125). An analysis of suitable types of metals to meet present day demands for long life, corrosion resistance and accuracy in springs is made. Types discussed are high-carbon steels, alloy spring steels, stainless, spring brass and bronze and special nickel alloys.—M. A. K.

Development of Watch Springs in Russia. V. V. Kryzhanovskii and N. M. Fedorov. (*Stal'*, 1957, (7), 656–657). Foreign imports were dispensed with in 1948. In 1950 a new technique for producing strip was introduced giving much longer life than the springs previously imported. Swiss S-springs were studied and torque higher than that from spiral springs was obtained. Stainless and non-magnetic alloys have been used for springs 0·16 × 1·35 mm, 0·12 × 1·50 mm and 0·09 × 1·25 mm and tests on these are given and compared with carbon steel and comparisons of the drop in torque in S— and spiral springs is also recorded. Stainless springs last 40 years but cost five times as much as carbon steel, it is therefore better to use the latter and replace them every 20 years. Stainless and non-magnetic alloy springs are only suitable for mechanisms operating in corrosive conditions, or up to 200° C, or for magnetic instruments.

How to Select Chrome-Moly Steels for Ball and Rod Mill Liners. T. E. Norman. (*Eng. Min. J.*, 1957, **158**, July, 102–106). The modes of wear and testing methods and service results with future outlook are also included.

Steels for Aircraft. R. B. Gunia. (*Metal Progress*, 1957, **71**, June, 104–105). A short review of the properties of a number of alloy steels suitable for use in aircraft construction is presented.—B. G. B.

Metals for Low Temperature. A. L. Tarr. (*Machine Design*, 1956, **28**, May 31, 111–116). The author discusses low temperature stress systems and material properties influencing selection of ferrous and non-ferrous alloys for low-temperature applications.—M. A. K.

Materials for High Temperatures. C. L. Clark. (*Machine Design*, 1956, **28**, May 31, 95–98). Familiar stainless and alloy steels, and high alloys of Ni, Cr and Co, are still the basic materials for high temperature performance, to meet military and commercial requirements. But competition from cermics, cermets and new metals is gaining ground.—M. A. K.

Protective Caps for Fractured Incisors. D. J. Stewart. (*Brit. Dental J.*, 1957, **102**, May 21, 404–406). Prefabricated stainless steel crowns and a design cut out of stainless sheet are described.

HISTORICAL

Iron in Prehistoric Times and in Antiquity. B. Bomi. (*Met. Ital.*, 1957, **49**, Mar., 65–67). [In Italian]. The author gives a brief review of prehistoric and early iron in the world. The article is illustrated.—M. D. J. B.

Examples of Comparative Analyes of Iron Specimens Coming from China (Han Epoch) and from Etruria. A. R. Weill. (*Rev. Mét.*, 1957, **54**, April, 270–276). The results of spectroscopic analysis of ancient specimens of iron from China and Etruria are given.—B. G. B.

Swedish Iron on the British Market in the 19th Century. A. Attman. (*Anglo-Swedish Review*, 1957, Apr., 160–163).

100 Years of Bessemer and 75 Years of Thomas Steel-Making Processes. E. Cotel. (*Kohászati Lapok*, 1955, **10**, Jan., 1–7). A critical review of the historical development of the Bessemer and basic Bessemer processes.—P. K.

MISCELLANEOUS

The Moscow Automatic Ball-Bearing Factory. P. Trippe. (*Metalworking Prod.*, 1957, **101**, Jan. 11, 49–70). The author describes a visit made to inspect an automatic factory in U.S.S.R. producing $1\frac{1}{2} \times 10^6$ bearings annually. The layout of the plant, economic factors and accuracy of the finished product are discussed.—M. A. K.

The Evolution of the Permanent Magnet: A Brief Review. H. J. M. van Embden. (*Philips Tech. Rev.*, 1956–57, **18**, (12), 358–360).

An Electron-Diffraction Study of the Transformation α-Fe_2O_3 to γ-Fe_2O_3. G. I. Finch and K. P. Sinha. (*Proc. Roy. Soc.*, 1957, **241A**, July 23, 1–8).

Accurate Determination of the Cell Dimensions of Magnetite. E. Z. Basta. (*Mineralogical Mag.*, 1957, **31**, June, 431–442). Analyses are given and cell dimensions of $a = 8{\cdot}3963$ Å at 18° were measured, also less pure samples were examined. Effect of ionic substution is discussed and the presence of defect structures with excess O_2 is suggested as one cause of the great variations of published values.

Magnetic and Electrical Anisotropies of the Iron Sulphide Single Crystal. T. Hihara, M. Murakami and E. Hirahara. (*J. Phys. Soc. Japan*, 1957, **12**, June, 743).

Manganese from Low-Grade Ores by the Ammonium Carbonate Process. J. Y. Welsh and D. W. Peterson. (*J. Met.*, 1957, **9**, June, 762–765).

The Epitaxial Growth and Oxidation of Nickel, Cobalt and Iron on Rocksalt. L. E. Collins and O. S. Heavens. (*Proc. Phys. Soc.*, 1957, **70**, Mar. 1, 265–281). An electron-diffraction study.

Thermodynamics of the Cu-Fe-S System at Matte Smelting Temperatures. W. A. Krivsky and R. Schuhmann jun. (*J. Met.*, 1957, **9**, July, Section 1, 981–988).

Magnetic Properties of Ferromagnetic Oxide Minerals as a Basis of Rock Magnetism. S. Akimoto. (*Advan. Phys.*, 1957, **6**, July, 288–298). Magnetites and titanomagnetites are discussed and the ternary diagrams given.

Use of Conversion Factors for Calculating Labour Productivity. E. S. Glikman and A. L. Starosel'skit. (*Stal'*, 1957, (2), 162–164). [In Russian]. In connection with a recent article by Ya. D. Kats the authors suggest that productivity at each stage should figure in the conversion coefficients, which could be found by using actual productivity relationships for different forms of production. Tabulations of productivity figures for the Petrovskii works are presented.

The Poisoning Effect of Vanadium Compounds and Alloys With Respect to Metallurgical Labour Protection in Hungary. I. Veres. (*Kohászati Lapok*, 1956, **11**, May, 211–217). The biocatalytic and toxic effects of compounds and alloys on animals and human beings are reviewed and the technical, as well as the industrial hygienic problems and tasks for the prevention and curing of vanadium poisoning are discussed in detail.—P. K.

BOOK NOTICES

BOËTHIUS, BERTIL, and ÅKE KROMNOW. "*Jernkontorets Historia.*" Dell III. "*Jernkontoret och Tekniken Före Götstålsprocesserna.*" Part 1, text; Part 2, supplement. La. 8vo, illustrated. Part 1, pp. xvi × 547; Part 2, pp. 213. Stockholm, 1955: Jernkontoret.

In connection with the bicentenary jubilee of Jernkontoret, 1947, the first volume of the History of Jernkontoret was published. In more than 600 pages this deals with the economic and commercial conditions leading up to the founding of this unique organization and follows its history during the first two decades. Emphasis is laid on the financial importance of Jernkontoret to the Swedish iron works, and according to plan the second volume should deal with the history up to about 1860 from the same general point of view. However, it was found necessary to deal first with Jernkontoret's very extensive engagements in the technical fields before a real grasp of the financial aspects could be obtained, and thus the third volume has appeared before the second.

The present volume deals in detail with the organization and gradual growth of the technical department of Jernkontoret and the activities of Sven Rinman, his colleagues and successors.

The period dealt with is one of momentous importance to the Swedish iron and steel industry. It lost for ever its earlier dominating position, but it survived. Of interest to British readers is the introduction in Sweden of the method of making charcoal wrought-iron used in Lancashire. This method became of great importance in Sweden, especially after Gustaf Ekman had invented his well-known heating furnace, which made possible the rolling of bar iron instead of the formerly prevalent forging.

The volume is published in two parts, of which the second has the character of an appendix. It contains a number of technical drawings, sources, a bibliography of books published by Jernkontoret or subsidized by this institution up to 1866, etc.—E. ÖHMAN.

CARTER, C. F., and B. R. WILLIAMS. "*Industry and Technical Progress.*" Factors Governing the Speed of Application of Science. 8vo, pp. viii × 244. London, 1957: Oxford University Press. (Price (in the U.K. only) 25*s*.).

Professor Carter and Professor Williams are economists who have set out to assess the factors governing the speed of application of Science in Industry. They write on behalf of the Science and Industry Committee sponsored by the British Association, the Royal Society of Arts, and the Nuffield Foundation to examine this question. The Board of Trade, the Department of Scientific and Industrial Research, and the Treasury have all had some part in providing the funds and asking the questions. A committee of accountants has assisted. Variety of inspiration has clearly not been lacking!

The basic material for the book has come from case studies of a sample of 152 firms in four industries (pottery, cutlery, jute, and paper-making), on which a team of research workers were employed. Much of the detail and statistics remains to be published later.

Readers must not expect to find here a simple clear recipe for the quick and spectacular application of the results of research; they will find most of the common nostrums exposed to careful analysis and revealed as part truths only. Big firms are not always the most progressive, nor small ones always backward; restrictive agreements are by no means always inimical to progress; a continental-size market is far from essential; scientists on the Board are not an infallible guide to success.

The authors deliberately emphasize the complexity of the picture revealed by the survey, but if there is a theme to be discerned it is that good management and co-operation between Production, Sales and Research, rather than technical skill, are the main need. Frustrated scientists and technicians will reflect how often it has seemed to them that it was clear enough what ought to be done but exceedingly difficult to succeed in getting it done.

The book will be of most use to economists, but it is so well written that it should give inspiration to all who have an interest in technical advance.—E. T. SARA.

"'*AnalaR*' *Standards for Laboratory Chemicals.*" Fifth Revised Edition. La. 8vo, pp. xvi + 397. London, 1957: The British Drug Houses, Ltd. and Hopkin & Williams, Ltd.

This work has long been familiar on laboratory shelves and the new edition is to be welcomed by all analysts as a guide to the purity of the reagents available and to the standards to be expected. A list of the items added and of those discontinued is given on p. v, and it appears strange that among the latter should be 3 : 5-dinitrobenzoyl chloride and sulphosalicylic acid. The most interesting additions are *p*-nitrophenylhydrazine, diphenylbenzidine—so useful for zinc titration—and EDTA, the last-named under the name of diaminoethanetetra-acetic acid. In general, the names have been modified where necessary to conform to British Standard 2474, 1954, but the more correct name for EDTA would surely be 1 : 2-*NNN′ N′-tetra*(carboxymethyl)diaminoethane on the model of Michler's ketone. The tests recorded show how far we have come from the days when the first operation in precise analysis was the removal of string and shavings from the contents of the reagent bottle; the reviewer well remembers the late Professor S. Sugden making this complaint.

It is scarcely possible to offer any criticism of the text, which is uniformly good, though perhaps the very sensitive test for ferrous iron with dimethylglyoxime buffered with ammonium acetate might sometimes be tried. As the contents are arranged in alphabetical order it might have been an improvement to have used, in the index, a system nearer to that of the abstract journals, thus dispersing the long lists under 'potassium' and 'sodium' under the acid radicals. These, however, are trifling matters, even as constructive criticisms, in relation to so excellent a work.

J. G. C.

BALDWIN, EDWARD N., and BENJAMIN W. NIEBEL. "*Design for Production.*" 8vo, pp. xii + 645. Illustrated. Homewood, Illinois, 1957: Richard D. Irwin, Inc. (Price $7.00).

This book is intended as a text-book for engineering and technical students who expect to become associated either with the design or with the production of articles which are required in very large numbers.

Fourteen chapters deal with the properties of materials and with specific processes such as casting, hot-working, cold-working, machining, etc. All of them give a general idea of the subject with which they deal, but in so far as absolute accuracy is concerned they leave much to be desired. Nevertheless the book is well worth reading solely on account of the remaining chapters. Chapter 1 deals with designing for production, Chapter 2 with sales considerations,

Chapter 3 economic considerations in the development of a product and Chapter 4 with product and process development procedures. Finally, the book concludes with chapters devoted to assembly, quality control, packaging, automation and patents and with three typical case histories. These case histories are particularly instructive, and may with advantage be read by all scientists and technicians who are in any way associated with a metal producing firm or with a mass-production engineering organisation.

J. F. KAYSER.

CHESTERS, J. H. "*Steelplant Refractories.*" Testing, Research and Development. Second edition (revised and completely rewritten). 8vo, pp. xi + 728. Illustrated. Sheffield, 1957: The United Steel Companies, Ltd. (Price 80*s.*).

This is the second edition of an admirable book, written by a man most competent to deal with the subject. Dr. Chesters' long association with research on refractory materials—particularly in connection with iron and steel manufacture—his wide experience of the many facets of the subject, his felicity of expression and his scientific approach have produced a book which is authoritative, and, at the same time, a clear and accurate statement.

The author has given considerable thought to the arrangement of his material. With a rapidly developing technology, it is clear that, without a good design, a book on refractory materials could be a very dull and confusing affair. The reviewer has found the arrangement in "Steelplant Refractories" most praiseworthy. By commencing with methods of testing, the author introduces a subject in a manner which must appeal to the student and practitioner alike. In Chapters II–VII the author covers the scientific background of the raw materials, manufacture and properties of the refractories used in the steel industry. His appreciation of the phase rule and its value in ceramics, his first-hand knowledge of X-ray techniques and their implications, his grasp of technological properties make the treatment of this section of the book very satisfying. Particularly so is the treatment of the super-duty silica brick, of chrome-magnesite products and of thermal insulation.

Chapters VIII–XIV are primarily concerned with the application of refractories in the different processes of steel manufacture. Here we have the full force of Dr. Chesters' outstanding experience. His knowledge of steel-furnace practice, based, in no small measure, on his keen interest in the scientific principles of furnace design, gives added importance to his subject. It is quite evident that the refractories technologist cannot be proficient without a very adequate knowledge of all the factors involved in use. Dr. Chesters indicates likely future improvements and developments in steel-making practice and the influence of such advances on refractory materials. This feature is intriguing and adds much to the reader's pleasure.

The bibliography is arranged so that any student can gain the maximum advantage in a short time. There are eighty pages of useful appendices. The illustrations are clear and can be readily understood. The book is well printed and has a stout binding. Dr. Chesters' book will be a lasting witness to his zeal and energy and a complete source of information to all interested in the manufacture and use of refractory materials in steel manufacture.

A. T. GREEN.

DE SMET, GÉRARD. "*La Pratique des Traitements Thermiques des Métaux Industriels.*" Cinquieme edition. Preface de G. Bouteiller. La. 8vo, pp. xxiv + 466. Illustrated. Paris 1957: Dunod. (Price 3,300 fr.).

Although this is the fifth edition of this book, there is much that can be criticised. Whilst there is a good deal of useful, practical information, it is felt that the theoretical background provided is inadequate. In certain instances the theoretical content is incorrect or out of date.

In the section dealing with the microstructural constituents of steel, for example, the terms troostite, sorbite and osmondite are used to describe different forms of tempered martensite, while bainite is only briefly mentioned. The term osmondite is now largely obsolete, while the author should have indicated that sorbite and troostite may be applied to other types of structure. The grain-size ranges on the A.S.T.M. scale are tabulated twice, but in neither instance does the author mention the magnification at which the number of grains per square inch is determined. Furthermore, the Cu–Sn and Cu–Zn equilibrium diagrams contain errors in both the temperatures and the delineation of the phase boundaries.

A rather sketchy section on the manufacture of steel and cast iron precedes what proves to be the main body of the book, namely, a detailed survey of carburising and nitriding practice. In fact, almost one quarter of the book is devoted to these treatments. The subsequent sections deal with tool steels, aluminium and copper alloys, surface treatments, furnace design, temperature measurement and mechanical testing in a rather superficial manner. The selection of subject matter is apparently closely linked with the requirements of anyone connected with the automobile industry, as is the author.

There are a number of criticisms one might make of the production of the book, particularly the very liberal sprinkling of errors. The majority of the mistakes are fairly obvious and thus tend to be more irritating than misleading. Thus, in several cases where a mathematical formula has been introduced, printing errors make nonsense of it, *e.g.*, one finds $M2$ instead of M^2 (page 95), d_2 instead of d^2, (page 444), and on page 122 an equation with two equality signs; the right-hand one should be a minus sign. Chemical formulæ have suffered in a similar manner; thus, 3Fe appears as Fe_3 (page 7), Fe_3C appears as Fe3C, etc.

The comprehensive table of contents at the beginning of the book makes up to some extent for the lack of an index, though in a book of this kind the latter would be more desirable. Some of the diagrams have been reproduced on too small a scale and lack explanatory notes. Where photomicrographs are used, their reproduction leaves much to be desired and the magnification is rarely stated.

Despite these criticisms, the chapters on case-hardening and nitriding would be useful to those interested in these forms of treatment.—G. LUCAS.

GRANGE, R. A., F. J. SHORTSLEEVE, D. C. HILTY, W. O. BINDER, G. T. MOTOCK and C. M. OFFENHAUER. "*Boron, Columbium, and Zirconium in Iron and Steel.*" (Alloys of Iron Research New Monograph Series). 8vo, pp. xiv + 533. Illustrated. New York, 1957: John Wiley & Sons, Inc.; London: Chapman & Hall, Ltd. (published for the Engineering Foundation). (Price 112*s.*).

This is the fourth volume in the New Alloys of Iron Monograph Series, which has the general object of providing comprehensive summaries of available data on the effect of selected metals on carbon steel, alloy steel and cast iron. Whilst there is no doubt some plan in their preparation, these volumes are appearing in a very random order. Following the three previous volumes on aluminium, nickel and titanium, this volume contains separate reviews of boron, calcium, columbium and zirconium. It will be noticed that this publication uses the name columbium instead of niobium (which was recommended by the International Union of Chemistry in 1949). The Iron Alloys Committee of the Engineering Foundation has ascertained that American metallurgists prefer the former name.

In a book which contains 533 pages, 54 are devoted to boron, 40 to calcium, 309 to columbium and 85 to zirconium. This difference probably reflects the amount of published literature but perhaps not the relative consumptions of the four elements. With the increased use of boron in low-alloy structural, 12% chromium and austenitic creep-resisting steels, the chapter on boron will probably soon have to be expanded.

There is no doubt that this volume will be extremely useful to any metallurgist interested in the effects of these elements, and certainly the reviews are the most comprehensive available. However, the literature references extend only to 1954, and, consequently, the reviews will rapidly become out of date. Many people would be interested to know what policy the Iron Alloys Committee has to meet this objection. Frequent reprints at the high price of this volume would be wasteful, but perhaps a yearly supplement covering all the alloying elements could be considered.

K. J. IRVINE.

GREAVES, RICHARD HENRY and HAROLD WRIGHTON. "*Practical Microscopical Metallography.*" Fourth edition, revised and enlarged. La. 8vo, pp. xiv + 221. Illustrated. London, 1957: Chapman & Hall, Ltd. (Price 70*s.*).

This fourth edition of one of the best known books in metallurgy maintains the level of its predecessors. As before, it commences with chapters on the preparation of

macro- and micro-specimens and on the technique of microscopy. These are followed by thirteen chapters that contain a most instructive account of the relation between the service properties, composition, heat-treatment and microstructure of steels, and alloys of copper, nickel, aluminium, magnesium and some other metals. Again, microstructures are illustrated in a profusion to be found in no other modern book. There is a final chapter on particular microscopical techniques such as phase-contrast and the use of polarised light. A copy of the third edition was not readily available to compare with the new one, but the reviewer's impression is that the new one is about half as large again. It contains a little more than 200 pages of text and over 400 micrographs.

There are few references, because the material in this book cannot easily be culled from journals. It consists rather of the strained essence of years of experience. The photographs of rather old fashioned microscopes at the beginning should not be allowed to give the impression that the book is out-of-date—the only respect in which this true is that it describes how to set up one's own equipment, select lenses and so on, which is probably not a bad background even for the user of a modern factory-adjusted outfit. Perhaps the fourth edition can best be summed up by saying that few books contain so much knowledge in so accessible a form.—D. McLean.

Johnstone, Robert Edgeworth and Meredith Wooldridge Thring. "*Pilot Plants, Models, and Scale-up Methods in Chemical Engineering.*" (McGraw-Hill Series in Chemical Engineering). 8vo, pp. xi + 307. Illustrated. New York, Toronto, London, 1957: McGraw-Hill Book Company, Inc. (Price 71*s.* 6*d.*).

This book is a useful and clearly written account of model theory and will be welcomed by those who wish to refresh their knowledge of the subject and its applications to chemical engineering. After describing the three approaches to the subject through the principle of similarity, dimensional analysis, and differential equations, the authors deal with applications to fluid flow, heat transfer, chemical reactors, furnaces and other miscellaneous equipment. References are given to most of the important works relating to the subject, and there is a general introduction on the use of model techniques.

The book contains practically no new material, but it is only fair to say that the authors do not claim that it is more than a "collection and systematizing of all aspects of current model theory." Nevertheless, the treatment might have been fuller, and have included, for instance, such matters as compressibility effects in fluid flow (Mach number is hardly mentioned), transient effects, surface tension phenomena. The treatment is also very conventional and might well have entered into some of the more subtle points—for example, the significance of the product of the Grashof and Prandtl numbers in free convection. Some of the latest ideas, such as vectorial dimensional analysis, are not mentioned at all.

The arguments could also have been demonstrated by the inclusion of more examples to enable the user to become familiar with the way the model laws work. There are no examples based on aerodynamics, which, after all, is one of the fields in which models have been most effectively employed. The book would also have been improved by examples of how the model technique has in fact actually been employed in engineering practice and of the shortcomings and difficulties, without which some of the authors' claims in Chapters 1 and 2 are merely ideological. Nevertheless, the information given has not, so far as the reviewer is aware, been previously collected together in such a readable form.—O. A. Saunders.

Lister, Raymond. "*Decorative Wrought Ironwork in Great Britain.*" 8vo, pp. xii × 265. Illustrated. London, 1957: G. Bell & Sons Ltd. (Price 35*s.*).

This book will be of value to all interested in architectural and domestic wrought-ironwork, and whilst it deals with the artistic side of wrought iron work, it is unusual to find in one volume such details of the technique of the smith—called by the author "Blacksmithery."

Through all the chapters—which include Technique, The Artistry of Wrought Ironwork, The Artistic and Practical Aspect of Domestic Ironwork, The History and the Personality of the Blacksmith—evidence is given of the author's practical knowledge of men and material, and his knowledge and enthusiasm extend to the beautiful uses of his material and a proper valuation of craftsmanship.

The work includes a useful glossary of terms, many strange to the layman, but homely to the worker in iron. An extensive bibliography completes the work.

It would be of increased value if this book could get into the hands of the practical smith, particularly to encourage the young smith in the maintenance of a really worthwhile and satisfying craft, and this is without doubt one of the chief aims of the author.

The subject covered is so large that perhaps it is unfair to criticise the rather brief reference to the material on which the smith works, but this is enlarged upon in the glossary under "Raw Materials."

As "Blacksmithery" (a word the reviewer does not like and one that is not included in the glossary) is so much an hereditary craft, it is a pleasure—on a personal note—to see the book dedicated to the author's parents.

This useful work makes one appreciate the history and work of the smith and will encourage the architect and antiquarian reader to follow up this subject.—P. Jump.

Rose, H. E., and A. J. Wood. "*An Introduction to Electrostatic Precipitation in Theory and Practice.*" 8vo, pp. 166. Illustrated. London, 1956: Constable & Co. Ltd. (Price 17*s.* 6*d.*).

The authors give a review of the problems of electroprecipitation and precipitator practice as used in England, particularly in the field of flue-gas cleaning. A thorough and critical study of the literature published up to 1955 lists the relevant formulæ and curves and discusses their validity in actual practice. The authors carried out some research on corona discharge *versus* voltage distribution under laminar and turbulent gas flow and the repelling of a dust layer from the receiving electrodes.

The authors recognise the difficulties opposing the formulation of an all-valid theory, and conclude that the conditions assumed in the derivation of theories of electroprecipitation do not hold in practice. Their discussion of electrical theory might have been clearer if the problems and application of single- and two-stage precipitation had been considered separately.

The authors admit that the present volume is neither a text book nor a design manual, but as a survey of published information the book makes a useful reference work for all interested in electroprecipitators.—R. F. Jennings.

Summer, W. "*Photosensitors.*" A treatise on Photo-Electric Devices and their Application to Industry. 8vo, pp. xvi × 675. Illustrated. London, 1957: Chapman & Hall, Ltd. (Price 105*s.*).

Dr. Summer has compressed a considerable amount of information into the six hundred pages of a book which should prove a very useful work of reference to engineers and scientists unfamiliar with the application of photosensitive devices. The degree of condensation, however, has had the result that, in many examples, reference to the orginal publication will be necessary to obtain adequate details of the topic in question.

Part I deals very effectively with the main types of photo-sensitive devices, together with the basic electric circuits needed for their operation. It is unusual to find in a book of this type chapters on physiological optics and the theory of colour vision, but their inclusion should be welcome to the application engineer who wishes to evaluate the performance of a human observer in relation to that of a photosensitor. Further useful chapters cover energy sources, optical systems and filters.

Part II covers known applications grouped in chapters under main classes of operations. So many are listed, however, that the detail given under each application is very scanty. As a guide to original publications, these chapters do fulfil a very useful function. It is difficult to find any present applications which are not listed, with the exception of size measurement. This is a field which should warrant a chapter in its own right rather than being covered somewhat haphazardly in other chapters.

The bibliography contains over 2600 references, of which a particularly pleasing feature is the inclusion of relevant British, American, German and French patents. Dr. Summer can be congratulated on writing a book which should prove an excellent introduction to a wide and complex field.—B. O. Smith.

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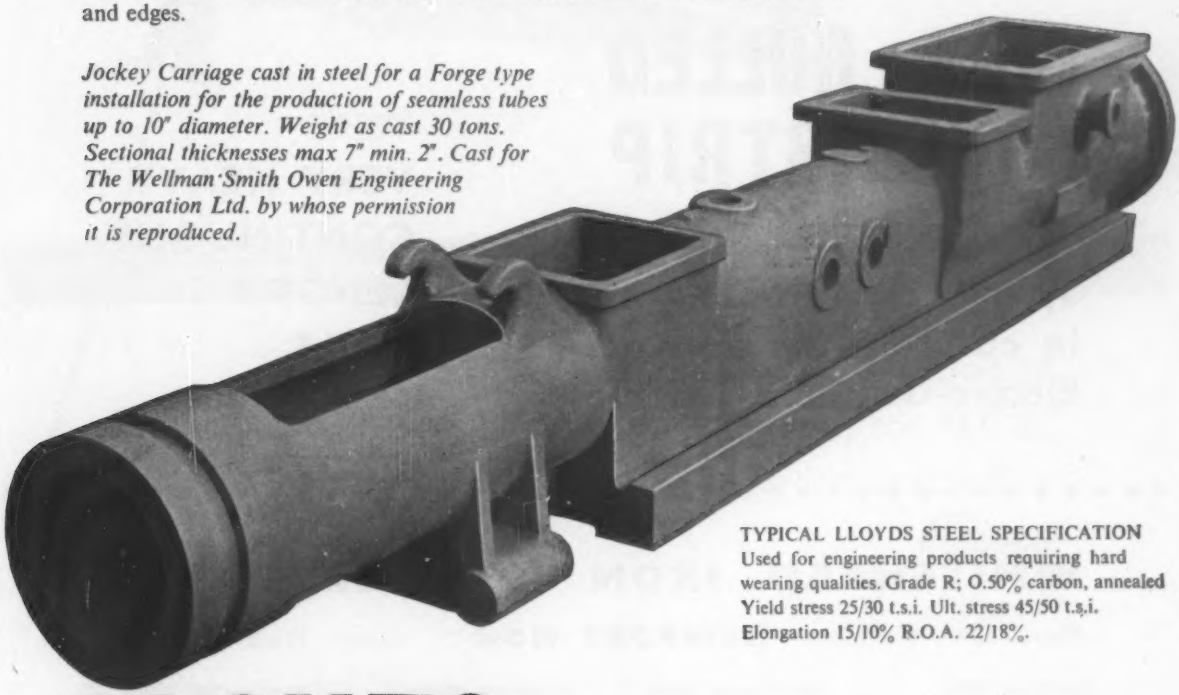

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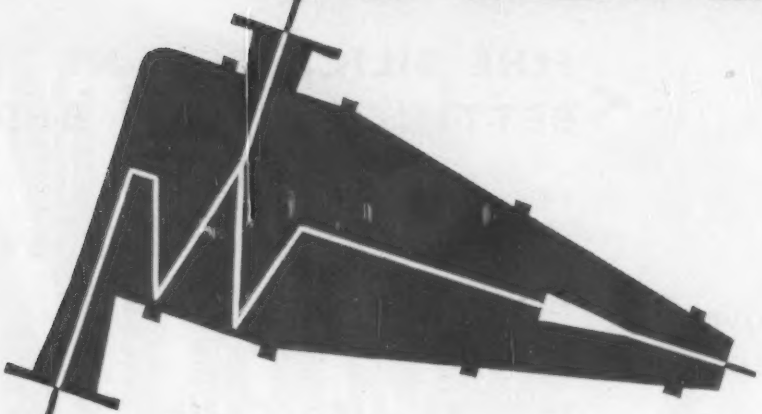

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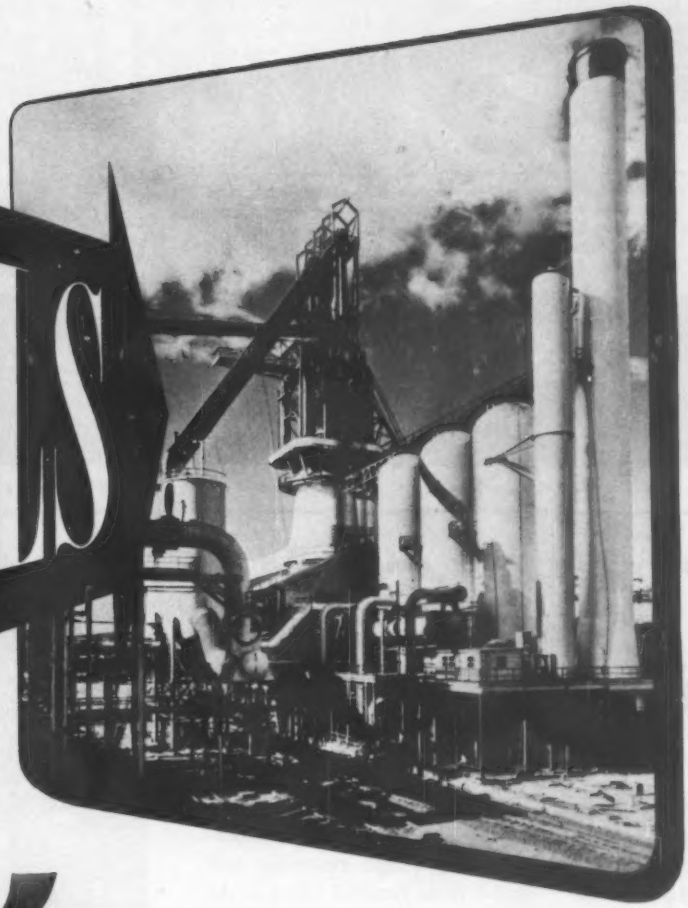

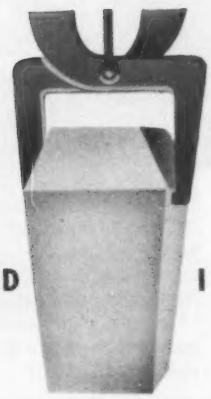

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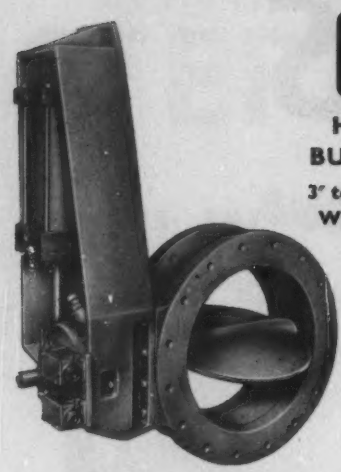

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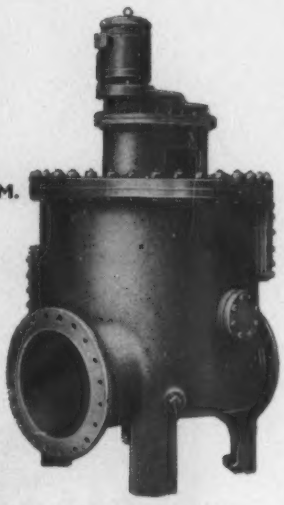

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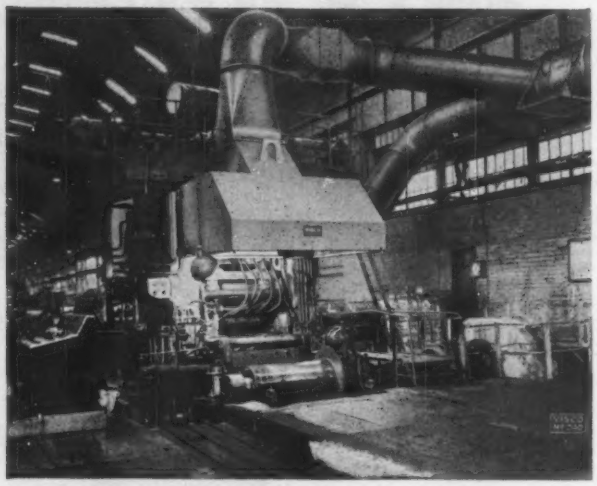

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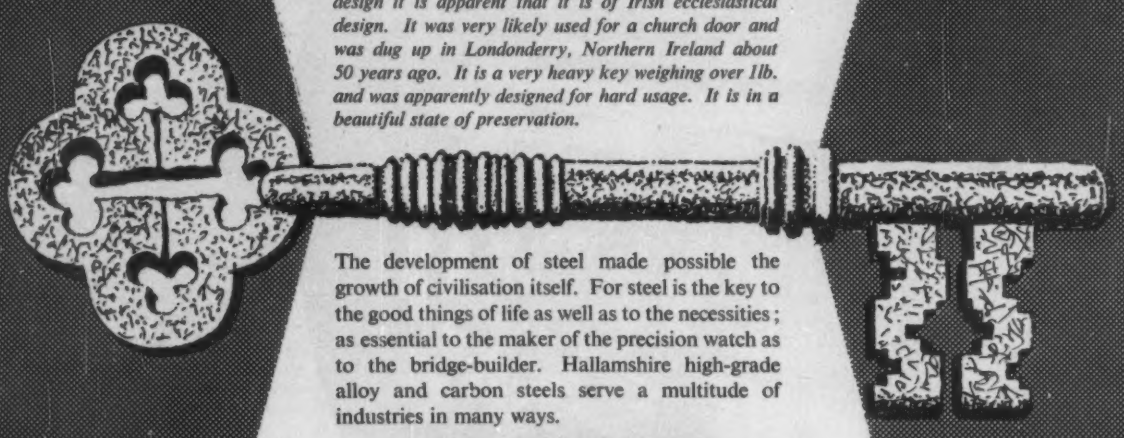

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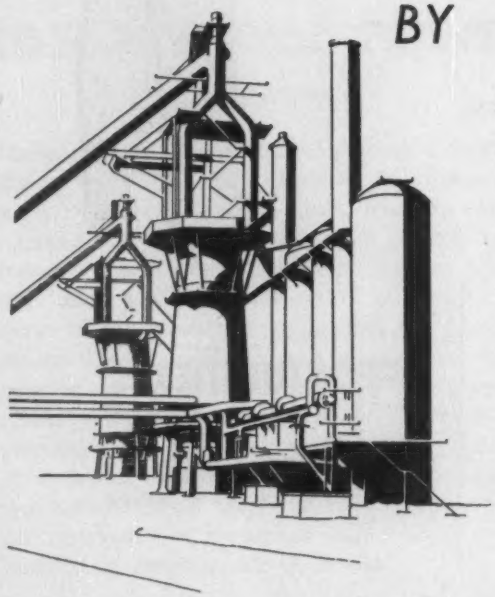

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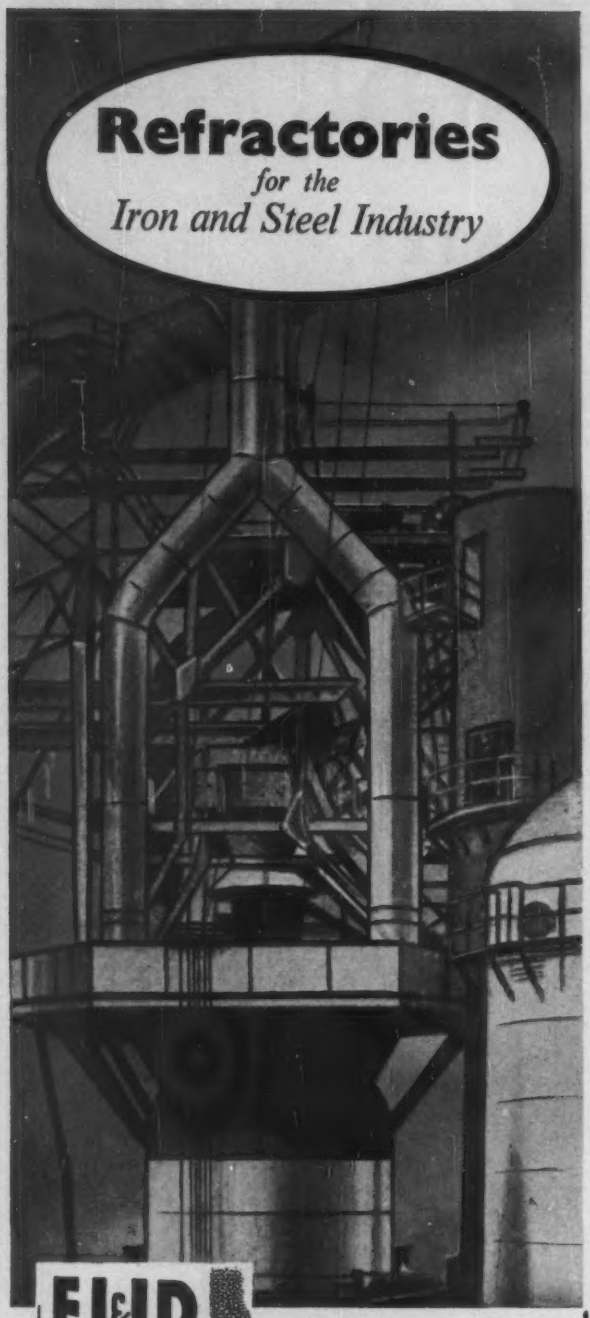

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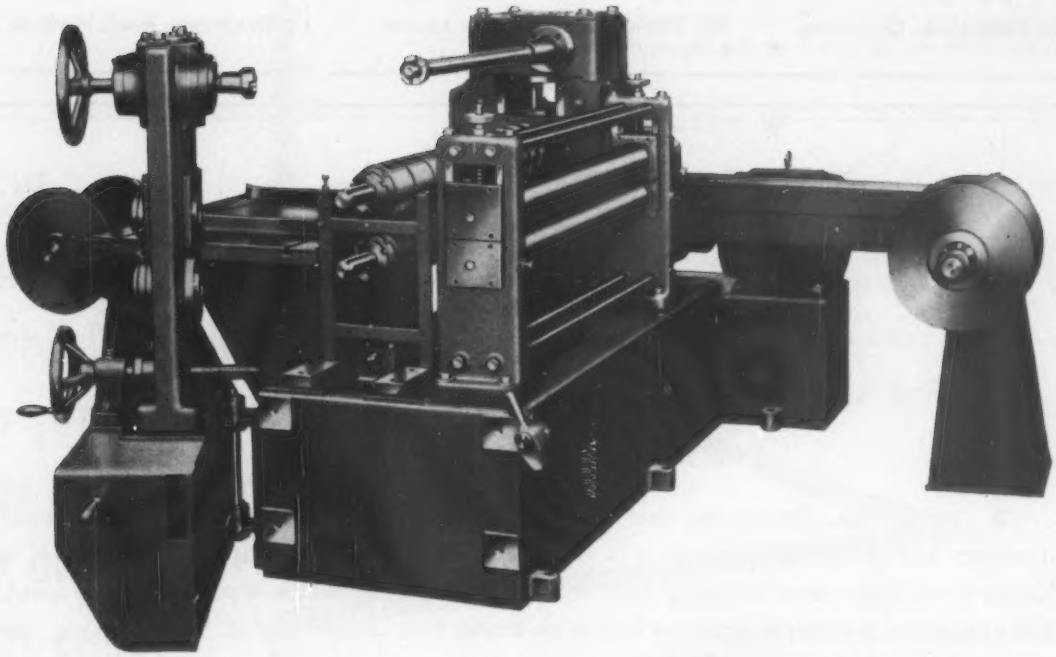

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Special Report No. 60

Proceedings of the

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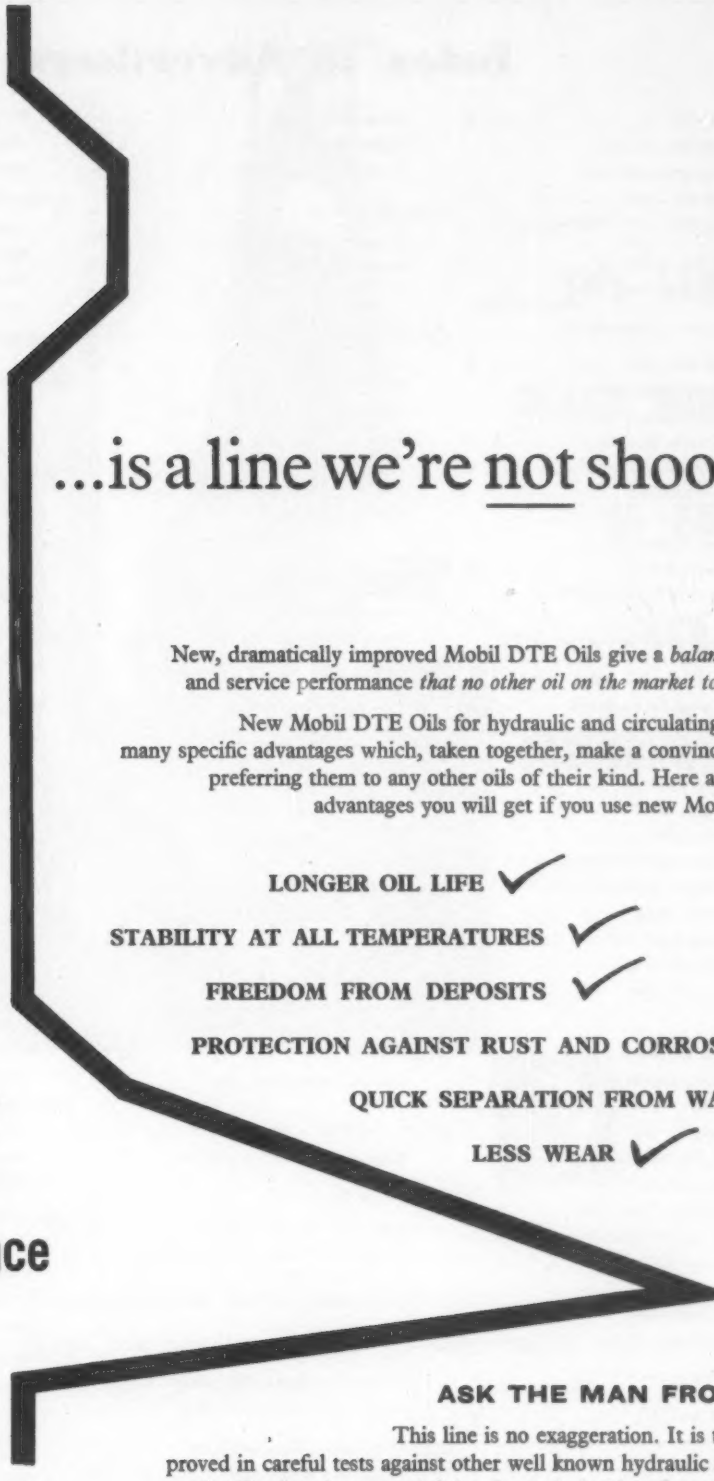
In October, 1954, The Iron and Steel Institute held a Joint Meeting with the National Forgemasters' Association and La Chambre Syndicale de la Grosse Forge Française. Technical Sessions were held in London at which nine papers on forging theory and practice and forging plant were presented and discussed. The remainder of the Meeting comprised visits to the English Steel Corporation Ltd., Thos. Firth and John Brown Ltd., and Hadfield Ltd., in Sheffield.

The Proceedings at the Technical Sessions have now been published as a Special Report. The five French papers and discussion are presented in English, but summaries of all the papers are also given in French. The Report, No. 60 in the Special Report series of the Institute, can be obtained from the Offices of the Institute, 4 Grosvenor Gardens, London, S.W.1, price 37*s.* 6*d.* (Members 25*s.*).



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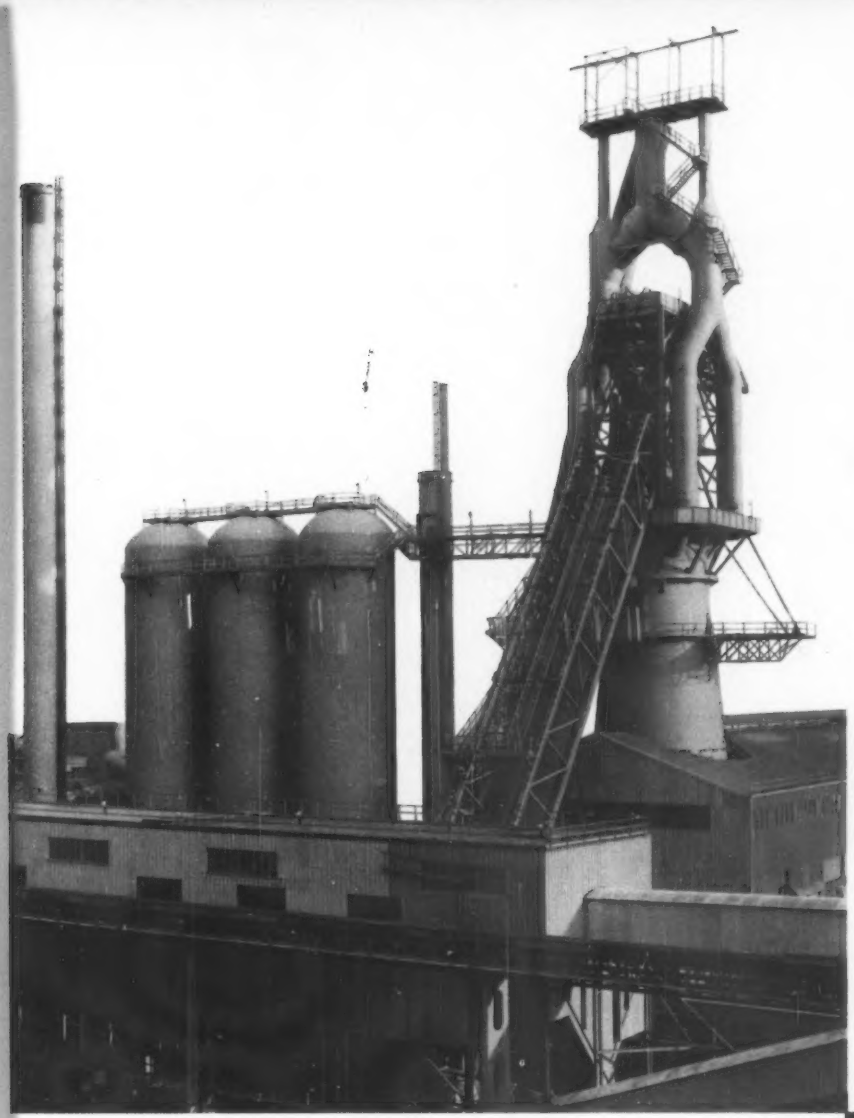

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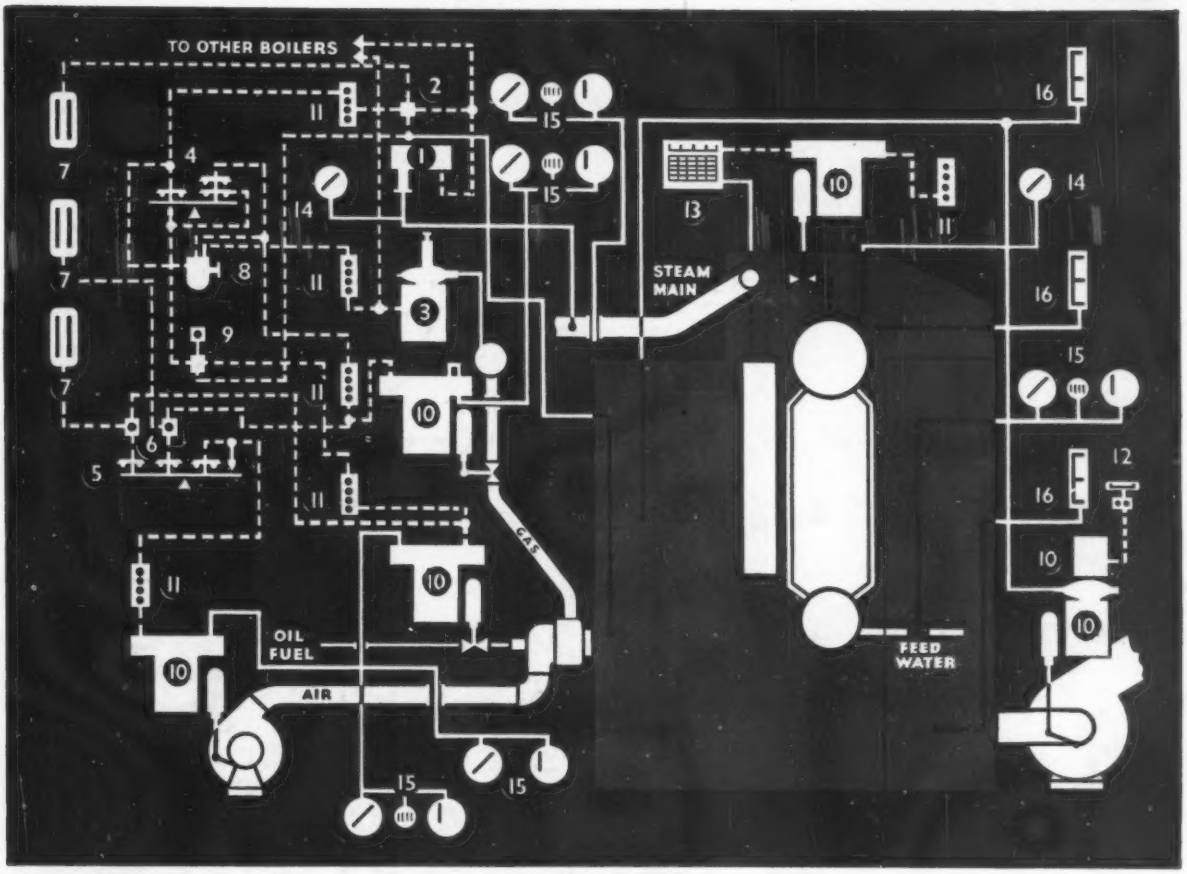

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